Marsh 15/—

ropertty of P. E. Cloud Duke
June 1940

O. C. Marsh

A MANUAL OF PALÆONTOLOGY

BY THE SAME AUTHOR.

I.

Second Edition, revised and enlarged.

A MANUAL OF ZOOLOGY,

FOR THE USE OF STUDENTS.

WITH A GENERAL INTRODUCTION ON THE PRINCIPLES OF ZOOLOGY, AND GLOSSARY OF SCIENTIFIC TERMS.

Crown 8vo, pp. 673, with 243 Engravings on Wood, 12s. 6d.

II.

TEXT-BOOK OF ZOOLOGY,

FOR THE USE OF SCHOOLS.

Crown 8vo, pp. 340, with 153 Engravings on Wood, 6s.

III.

INTRODUCTORY TEXT-BOOK OF ZOOLOGY,

FOR THE USE OF JUNIOR CLASSES.

With 127 Engravings, 3s. 6d.

IV.

ESSAY ON THE GEOLOGY OF CUMBERLAND AND WESTMORELAND.

Octavo, with Engravings, 3s. 6d.

V.

A MONOGRAPH OF THE BRITISH GRAPTOLITIDÆ.

Octavo, with Engravings, 5s.

VI.

INTRODUCTION TO THE STUDY OF BIOLOGY.

Crown 8vo, with numerous Engravings, 5s.

VII.

TEXT-BOOK OF GEOLOGY,

FOR SCHOOLS AND COLLEGES.

Crown 8vo, with Illustrations.

P. E. Cloud, June 1940

A

MANUAL OF PALÆONTOLOGY

FOR THE USE OF STUDENTS

WITH A GENERAL INTRODUCTION ON THE PRINCIPLES OF PALÆONTOLOGY

BY

HENRY ALLEYNE NICHOLSON

M.D. D.Sc. M.A. Ph.D. F.R.S.E. F.G.S. &c.

PROFESSOR OF NATURAL HISTORY AND BOTANY IN UNIVERSITY COLLEGE, TORONTO;
FORMERLY LECTURER ON NATURAL HISTORY IN THE MEDICAL SCHOOL
OF EDINBURGH; ETC. ETC.

WILLIAM BLACKWOOD AND SONS
EDINBURGH AND LONDON
MDCCCLXXII

1872

BLH

PREFACE.

THE object of the present work is to furnish the student of Geology and the general reader with a compendious account of the leading principles and facts of the vast and ever-increasing science of Palæontology. In carrying out this object, all superfluous details have been rigidly excluded, and the Author has endeavoured to restrict himself entirely to those facts which are absolutely necessary to any one who would study Palæontology as a department of science, sufficiently distinct to stand alone, and yet most closely connected with the sciences of Zoology and Botany on the one hand, and with Geology on the other hand.

In the First Part of the work is given a general account of the principles upon which the palæontological observer proceeds.

In the Second Part of the work, Palæontology, or the past history of the Animal Kingdom, is treated of; and here much more space has been devoted to the Invertebrate than to the Vertebrate groups—upon the ground that it is chiefly, or almost exclusively, with the former that the ordinary palæontological student has to deal.

The Third Part of the work gives a brief and very general view of Palæobotany, or the past history of the

Vegetable Kingdom. This department of the subject has not been treated at any length, partly because the remains of plants are comparatively rare in the stratified series, and partly because nothing less than a special treatise would suffice to handle satisfactorily this obscure and difficult branch of the subject.

The fourth and concluding portion of the work treats of Historical, or, as it might be called, Stratigraphical, Palæontology—namely, of the application of Palæontology to the elucidation of the succession of the stratified deposits of the earth's crust. This department of the subject has also been very briefly disposed of, not because its intrinsic importance does not warrant a more extended treatment, but because it is the Author's intention, as his leisure will permit, to devote a separate treatise to the consideration of this wide and comparatively independent section of the science.

In conclusion, the Author would beg his readers to remember that there is no science which is growing so rapidly, and which is as yet so comparatively in its infancy, as Palæontology; and that there is none in which the conclusions of to-day are more liable to be vitiated by the discoveries of the morrow. Even whilst these sheets have been going through the press, facts have been brought to light which ought to have found their place in a Manual of this kind, but which have been of necessity altogether passed over, or, at best, have been merely alluded to. For all deficiencies, therefore, arising from this cause, the Author has to beg the kind indulgence of his readers.

With regard to the Illustrations, the Author has gratefully to acknowledge the kindness of Alfred R. C.

Selwyn, Esq., Director of the Geological Survey of Canada, who placed at the Author's disposal a number of engravings of Silurian and Devonian fossils, from the publications of the Survey. The Author has likewise to acknowledge a similar obligation to Principal Dawson, of M'Gill University, Montreal, who kindly permitted the use of several of the illustrations of his 'Acadian Geology.' A considerable proportion of the engravings, however, are taken from D'Orbigny's beautifully illustrated 'Cours Elémentaire de Paléontologie,' by an arrangement with the publishers of that work.

UNIVERSITY COLLEGE, TORONTO,
October 16, 1872.

CONTENTS.

PART I.—GENERAL INTRODUCTION.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

CHAPTER VI.

PART II.—PALÆOZOOLOGY.

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

CHAPTER X.

CHAPTER XI.

CHAPTER XII.

CHAPTER XIII.

CHAPTER XIV.

CHAPTER XV.

CHAPTER XVI.

CHAPTER XVII.

CHAPTER XVIII.

CHAPTER XIX.

CHAPTER XX.

CHAPTER XXI.

CHAPTER XXII.

CHAPTER XXIII.

CHAPTER XXIV.

CHAPTER XXV.

CHAPTER XXVI.

CHAPTER XXVII.

CHAPTER XXVIII.

CHAPTER XXIX.

CHAPTER XXX.

CHAPTER XXXI.

CHAPTER XXXII.

CHAPTER XXXIII.

CHAPTER XXXIV.

CHAPTER XXXV.

CHAPTER XXXVI.

CHAPTER XXXVII.

CHAPTER XXXVIII.

CHAPTER XXXIX.

CHAPTER XL.

CHAPTER XLI.

CHAPTER XLII.

PART III.—PALÆOBOTANY.

CHAPTER XLIII.

CHAPTER XLIV.

CHAPTER XLV.

CHAPTER XLVI.

PART IV.—HISTORICAL PALÆONTOLOGY.

CHAPTER XLVII.

CHAPTER XLVIII.

PART I.

GENERAL INTRODUCTION

PALÆONTOLOGY.

CHAPTER I.

INTRODUCTION.

Definition of Palæontology.

Palæontology (Gr. *palaios*, ancient; *onta*, beings; *logos*, discourse) is the science which treats of the living beings, whether animal or vegetable, which have inhabited this globe at past periods in its history. It is the ancient life-history of the earth, and if its record could ever be completed, it would furnish us with an account of the structure, habits, and distribution of all the animals and plants which have at any time flourished upon the land-surfaces of the globe or inhabited its waters. From causes, however, which will be subsequently discussed, the palæontological record is most imperfect, and our knowledge is interrupted by gaps which not only bear a large proportion to our solid information, but which in many cases are of such a nature that we can never hope to have them filled.

As Zoology, then, treats of the animals now inhabiting the earth, and as Botany treats of the now existing plants, Palæontology may be considered as the Zoology and Botany of the past. Regarding it from this, the only true point of view, some knowledge of Zoology and Botany is essential to a prosecution of the study of Palæontology, and such details of these sciences as may be deemed requisite will be introduced in the proper place. The materials, again, which fall to be studied by the palæontologist, are derived entirely from the proper province of the geologist. *Fossils* are derived from *rocks*. It will therefore be necessary to trespass to some ex-

tent upon the peculiar domain of the geologist, and to obtain some knowledge of the origin, composition, and mode of occurrence of the rocks from which Palæontology derives its materials. Lastly, Palæontology, apart from its own importance as an independent science, is employed by the geologist to assist him in his determination of the chronological succession of the materials which compose the crust of the earth. Palæontology, therefore, must be separately studied in its relation to historical Geology.

Definition of Fossils.

All the natural objects which come to be studied by the palæontologist are termed "fossils" (Lat. *fossus*, dug up). In most cases, fossils, or, as they are often termed, "petrifactions," are actual portions of animal or vegetable organisms, such as the shells of Molluscs, the skeletons of Corals, the bones of Vertebrate animals, the wood, bark, or leaves of plants, &c.; and these may be preserved very much in their original condition, or may have been very much altered by changes subsequent to their burial. Strictly speaking, however, by the term "fossil" is understood "any body, *or the traces of the existence of any body*, whether animal or vegetable, which has been buried in the earth by natural causes" (Lyell). We shall find, therefore, that we must include under the head of fossils objects which at no time themselves formed parts of any animal or vegetable, but which, nevertheless, point to the former existence of such organisms, and enable us to reason as to their nature. Under this head come such fossils as the moulds or "casts" of shells and the footprints left by various animals upon sand or mud.

In the great majority of cases fossils are the remains of animals or plants which are now *extinct*—that is to say, which no longer are in existence, but have entirely disappeared from the earth's surface. In some cases, however, fossils are the remains of *recent* animals—that is, of animals which are still found in a living condition upon the globe. The term "subfossil," sometimes applied to these, has been more appropriately applied in another sense, and is best discarded in this connection. The terms "fauna" and "flora" are employed in Palæontology much as they are by the naturalist, to mean the entire assemblage of the animals or of the plants respectively belonging to a particular region or a particular time. Thus we may speak of the "fauna" of the Carboniferous Period, or the "flora" of the Tertiary Epoch, or the fauna of the Chalk, or of any other set of beds.

Fossilisation.

Fossilisation may be applied in a general sense to all the processes through which an organic body passes in order to become a fossil. Here we need only consider the three leading forms in which fossils present themselves. In the first instance, the fossil is to all intents and purposes an actual organic remain, being itself a fragment of an animal or plant. Thus we may meet with fossil bones, shells, or wood, which may have undergone certain changes, such as would be produced by pressure, by the deprivation of organic matter originally present, or by more or less complete infiltration with mineral matter, but which, nevertheless, are practically the real bodies they represent. As a matter of course, it is in the more modern formations that we find fossils least changed from their primitive condition, but all formations almost contain some fossils in which the original structure is more or less completely retained.

In the second place, we very frequently meet with fossils in the state of "casts" or moulds of the original organic body. What occurs in this case will be readily understood if we imagine any common bivalve shell, as an Oyster, or Mussel, or Cockle, embedded in clay or mud. If the clay were sufficiently soft and fluid, the first thing would be that it would gain access to the interior of the shell and would completely fill up the space between the valves. The pressure, also, of the surrounding matter would insure that the clay would everywhere adhere closely to the exterior of the shell. If now we suppose the clay to be in any way hardened so as to be converted into stone, and if we were to break up the stone, we should obviously have the following state of parts. The clay which filled the shell would form an accurate cast of the *interior* of the shell, and the clay outside would give us an exact impression or cast of the *exterior* of the shell (fig. 1). We should have, then, two casts, an interior and an exterior, and the two would be very different to one another, since the inside of a shell is very unlike the outside. In the case, in fact, of many univalve shells, the interior cast is so unlike the exterior or unlike the shell itself, that it may be difficult to determine the true origin of the former.

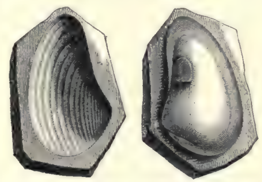


Fig. 1.—*Trigonia longa*, showing casts of the exterior and interior of the shell. —Neocomian.

It only remains to add that there is sometimes a further complication. If the rock be very porous and permeable by water, it may happen that the original shell is entirely dissolved away, leaving the interior cast loose, like the kernel of a nut, within the case formed by the exterior cast. Or it may happen that subsequent to the attainment of this state of things, the space thus left vacant between the interior and exterior cast—the space, that is, formerly occupied by the shell itself—may be filled up by some foreign mineral deposited there by the infiltration of water. In this last case the splitting open of the rock would reveal an interior cast, an exterior cast, and finally a body which would have the exact form of the original shell, but which would be really a much later formation, and which would not exhibit under the microscope the minute structure of shell.

In the third class of cases we have fossils which present with the greatest accuracy the external form, and even sometimes the internal minute structure, of the original organic body, but which, nevertheless, are not themselves truly organic, but have been formed by a "replacement" of the particles of the primitive organism by some mineral substance. The most elegant example of this is afforded by fossil wood which has been "silicified" or converted into flint. In this case we have a piece of fossil wood, which presents the rings of growth and fibrous structure of wood, and which under the microscope exhibits even the minutest vessels which characterise ligneous tissue. The whole, however, instead of being composed of the original carbonaceous matter of the wood, is now converted into pure flint. The only explanation which can be given of this by no means very rare phenomenon, is that the wood must have undergone a slow process of decay in water holding silica or flint in solution. As each particle of the wood was removed by decay, its place was taken by a particle of flint deposited from the surrounding water, till ultimately the entire wood was silicified. The replacing substance is by no means necessarily flint, but may be iron-pyrites, oxide of iron, sulphur, &c.; and it is not uncommon to find many other fossils besides wood preserved in this way, such as shells, corals, or sponges.

Definition of Rock.

The crust of the earth consists of various different materials, produced at different successive periods, occupying certain definite spaces, and not confusedly mixed together, but, on the contrary, exhibiting a definite and discoverable order of arrange-

ment. All these materials, however different in appearance, texture, or mineral composition, are called "rocks" by the geologist. The term "rock," then, is to be understood as applying to *all* the materials which compose the crust of the earth. In the language of geology, the finest mud, the loosest sand, and the most incoherent gravel, are just as much *rocks* as are the hardest and most compact granites or limestones.

Classification of Rocks.

For the purposes of the palæontologist all the rocks which enter into the composition of the solid exterior of the earth may be divided into two great classes:—1. The Igneous Rocks, which are formed within the body of the earth itself, and which owe their structure and origin to the action of heat; and 2, the Aqueous or Sedimentary Rocks, which are formed at the surface of the earth, and which owe their structure and origin to the mechanical action of water. The Igneous Rocks are formed below the surface of the earth, are as a general rule destitute of organic remains or fossils, and are mostly in the form of *unstratified* masses. The Aqueous and Sedimentary Rocks are formed at the surface by the disintegration and reconstruction of previously existing rocks, are mostly fossiliferous, and are *stratified—i.e.*, are arranged in distinct layers or "strata." The Sedimentary Rocks, as containing fossils, are the only rocks which it is essential for the palæontologist to be acquainted with, and we shall very briefly consider their leading physical characters, their chief varieties, their mode of origin, and their historical succession.

CHAPTER II.

SEDIMENTARY ROCKS.

The Sedimentary or Fossiliferous Rocks form the greater portion of that part of the earth's crust which is open to our examination, and are distinguished by the fact that they are regularly "stratified," or arranged in distinct and definite layers or "strata." These layers may consist of a single material, as in a block of sandstone, or they may consist of different materials. When examined on a large scale, they are always found to consist of alternations of layers of different mineral

composition. We may examine any given area, and find in it nothing but one kind of rock—sandstone, perhaps, or limestone. In all cases, however, if we extend our examination sufficiently far, we shall ultimately come upon different rocks; and, as a general rule, the thickness of any particular set of beds is comparatively small, so that different kinds of rock alternate with one another in comparatively small spaces.

As regards the origin of the Sedimentary Rocks, they are for the most part "derivative" rocks, being derived from the wear and tear of pre-existent rock. Sometimes, however, they owe their origin to chemical or vital action, when they would more properly be spoken of simply as Aqueous Rocks. As to their mode of deposition, we are enabled to infer that the materials which compose them have formerly been spread out by the action of water, from what we see going on every day at the mouths of our great rivers, and on a smaller scale wherever there is running water. Every stream, where it runs into a lake or into the sea, carries with it a burden of mud, sand, and rounded pebbles, derived from the waste of the rocks which form its bed and banks. When these materials cease to be impelled by the force of the moving water they sink to the bottom, the heaviest pebbles, of course, sinking first, the smaller pebbles and sand next, and the finest mud last. Ultimately, therefore, as might have been inferred upon theoretical grounds, and as is proved by practical experience, every lake becomes a receptacle for a series of stratified rocks produced by the streams flowing into it. These deposits may vary in different parts of the lake, according as one stream brought down one kind of material and another stream contributed another material; but in all cases the materials will bear ample evidence that they were produced, sorted, and deposited by running water. The finer beds of clay or sand will all be arranged in thicker or thinner layers or laminæ; and if there are any beds of pebbles these will all be rounded or smooth, just like the water-worn pebbles of any brook-course. In all probability, also, we should find in some of the beds the remains of fresh-water shells or plants or other organisms which inhabited the lake at the time these beds were being deposited.

In the same way large rivers—such as the Ganges or Mississippi—deposit all the materials which they bring down at their mouths, forming in this way their "deltas." Whenever such a delta is cut through, either by man or by some channel of the river altering its course, we find that it is composed of a succession of horizontal layers or strata of sand or mud, varying in mineral composition, in structure, or in grain, according to

the nature of the materials brought down by the river at different periods. Such deltas, also, will contain the remains of animals which inhabit the river, with fragments of the plants which grew on its banks, or bones of the animals which lived in its basin.

Lastly, the sea itself—irrespective of the materials delivered into it by rivers—is constantly preparing fresh stratified deposits by its own action. Upon every coast-line the sea is constantly eating back into the land and reducing its component rocks to form the shingle and sand which we see upon every shore. The materials thus produced are not, however, lost, but are ultimately deposited elsewhere in the form of new stratified accumulations, in which are buried the remains of animals inhabiting the sea at the time.

Whenever, then, we find anywhere in the interior of the land any series of beds having these characters—composed, that is, of distinct layers, the particles of which, both large and small, show distinct traces of the wearing action of water—whenever and wherever we find such rocks, we are justified in assuming that they have been deposited by water in the manner above mentioned. Either they were laid down in some former lake by the combined action of the streams which flowed into it; or they were deposited at the mouth of some ancient river, forming its delta; or they were laid down at the bottom of the ocean. In the first two cases, any fossils which the beds might contain would be the remains of fresh-water or terrestrial organisms. In the last case, the majority, at any rate, of the fossils would be the remains of marine animals.

The term "formation" is employed by geologists to express "any group of rocks which have some character in common, whether of origin, age, or composition" (Lyell); so that we may speak of stratified and unstratified formations, aqueous or igneous formations, fresh-water or marine formations, and so on.

Chief Divisions of the Aqueous Rocks.

The Aqueous Rocks may be divided into two great sections, the Mechanically-formed and the Chemically-formed, including under the last head all rocks which owe their origin to vital action, as well as those produced by ordinary chemical agencies.

A. Mechanically-formed Rocks.—These are all those Aqueous Rocks of which we can obtain proofs that their particles have been mechanically transported to their present

site. Thus, if we examine a piece of conglomerate or pudding-stone, we find it to be composed of a number of rounded pebbles embedded in an enveloping paste or matrix. The pebbles are worn and rounded, and thus show that they have been subjected to much mechanical attrition, whilst they have been mechanically transported for a greater or less distance from the rock of which they originally formed part. In the case of an ordinary sandstone, the component grains of sand are equally the result of mechanical attrition, and have been equally transported from a distance. In the case of still finer rocks, such as shale, the particles have been so much water-worn that their source cannot be recognised, though a microscopical examination would reveal that their edges were all worn and rounded. It follows from this that the mechanically-formed Aqueous Rocks are such as can be proved to have been *derived* from the abrasion of other pre-existent rock : hence they are often spoken of as "Derivative Rocks." Every bed, therefore, of any mechanically-formed rock, is an exact equivalent of a corresponding amount of destruction of some older rock.

The Mechanically-formed Rocks may be divided into the two groups of the Arenaceous or Siliceous Rocks, and the Argillaceous or Aluminous Rocks. In the Arenaceous group are those Aqueous Rocks which are mainly composed of smaller or larger grains of flint or silica. The chief varieties are the various kinds of sand and sandstone, grits, and most conglomerates and breccias. In the Argillaceous group are those Aqueous Rocks which contain a certain amount of clay or hydrated silicate of alumina. Under this head come clays, shales, marls, clay-slate, and most flags or flag-stones.

B. CHEMICALLY-FORMED ROCKS.—In this section are comprised all those Aqueous Rocks which have been formed by chemical agencies. As many of these chemical agencies, however, are exerted through the medium of living beings, whether animals or plants, we get into this section a number of what may be called "organically-formed" rocks. The most important of the Chemically-formed Rocks are the so-called Calcareous Rocks, comprising all those which contain a large proportion of carbonate of line, or are wholly made up of this substance. We may also shortly notice coal and gypsum.

Chalk is merely a limestone which is soft and pulverulent, with an earthy fracture. It is nearly pure carbonate of lime, and is to a great extent an organically-formed rock, consisting mainly of the minute calcareous shells of *Foraminifera*, with the calcareous shells of molluscs, sea-urchins, sea-mosses, and

the like. The nearest approach which we have at the present day to chalk is probably to be found in the deposit called "ooze," which forms a considerable portion of the bed of the deep Atlantic, and which will be afterwards noticed at greater length.

Limestone is a hard and compact rock, and its many varieties are formed in different ways, and differ from one another in more or less important points. Though the sea contains carbonate of lime in solution, no marine limestones appear to be formed by chemical agency alone, but in all these the lime is abstracted from the sea-water by the agency of marine animals. Primarily, therefore, marine limestones are organically-formed rocks, consisting almost entirely of corals, shells, Crinoids, and other calcareous organisms. Such limestones may fairly be compared to the great coral-reefs of the Pacific and other warm seas. It is to be remembered, however, that many marine limestones are secondarily mechanically-formed rocks. In these cases, the calcareous matter of the rock has been originally separated by living beings, but has then been transported by the waves, or by currents, to certain localities at a distance, where it has been heaped up to form a bed of limestone.

Other limestone deposits, such as the stalactites and stalagmites of caves, and the "calcareous tufa" and "travertine" of some hot springs, are purely chemical in their origin, and owe nothing to the operation of living beings.

Gypsum, in chemical composition, consists of sulphuric acid in combination with lime and two atoms of water; or, in other words, it is a hydrated sulphate of lime. It commonly occurs as a whitish or yellowish-white rock, something like loaf-sugar to look at, generally arranged in distinct beds, but sometimes in irregular cakes or veins. It is palæontologically important as occasionally yielding well-preserved fossils; but its exact mode of origin has not yet been fully worked out.

Coal is, in all those forms to which the name would ordinarily be applied, an organically-formed rock, and may be regarded as formed of compressed vegetable matter. In all its varieties—such as bituminous coal, anthracite, and lignite or brown coal,—it approximates more or less closely in chemical composition to wood. It consists, namely, of from seventy to eighty per cent of pure carbon, with varying quantities of hydrogen and oxygen, and a small amount of earthy or mineral matter which constitutes the ash. All coals occur in the form of beds, intercalated with other stratified rocks; and there are innumerable gradations between pure coal, earthy coal, and carbonaceous shale, till we reach ordinary shale.

Different Ages of the Aqueous Rocks.

The two principal tests by which the age of any particular bed, or group of beds, may be determined, are superposition and organic remains—a third test sometimes being afforded by mineral characters. The first and most obvious test of the age of any aqueous rock is its relative position to other rocks. Any bed or set of beds of sedimentary origin is obviously and necessarily older than all the strata which surmount it, and younger than all those upon which it rests. It is to be remembered, however, that superposition can at best give us but the *relative* age of a bed as compared with other beds of the same region. It cannot give us the *absolute* age of any bed; and if we are ignorant of the age of any of the beds with which we may be dealing, we have to appeal to other tests to learn more than the mere order of succession in the particular region under examination.

The second, and in the long-run more available, test of the ages of the different sedimentary beds, is that afforded by their organic remains. Still, this test is also by no means universally applicable, nor in all cases absolutely conclusive. Many aqueous rocks are unfossiliferous through a thickness of hundreds, or even thousands, of feet of little altered sediments; and even amongst beds which do contain fossils, we often meet with strata of a few feet or yards in thickness, which are wholly destitute of any traces of life. Many fossils, again, range vertically through many groups of strata, and in some cases even through several formations. Such fossils, therefore, if occurring by themselves, or considered apart from other associated organisms, are not conclusive as to the age of any particular set of beds. As the result, however, of combined palæontological and geological researches, it is now possible for us to divide the entire series of stratified deposits into a number of definite rock-groups or formations, each of which is characterised by possessing an assemblage of organic remains which do not occur in association in any other formation. Such an assemblage of fossils, characteristic of any given formation, represents the *life* of the particular period in which the formation was deposited. It follows from this, that whenever we can get a group or collection of fossils from any particular bed or set of beds, there is rarely any difficulty in determining the precise geological horizon of the beds in which the fossils occur.

With certain limitations, however, we may go much further than this. Not only are the great formations characterised by

special and characteristic assemblages of animals and plants; but, in a general way, each subdivision of each formation has its own peculiar fossils, by which it may be recognised by a skilled worker in palæontology. Whenever, for instance, we meet in Britain with the fossils known as Graptolites, we may be sure that we are dealing with Silurian Rocks. We may, however, go much further than this. If the Graptolites belong to certain genera, we may be sure that we are dealing with *Lower* Silurian Rocks. Furthermore, if certain special forms are present, we may be even able to say to what exact part or subdivision of the Lower Silurian series they belong.

All these conclusions, however, would have to be accompanied by a tacit but well-understood reservation. No Graptolites have ever been found in Britain out of rocks known upon other grounds to be Silurian; but there is no reason why they might not at any time be found in younger deposits. In the same way, the species and genera which we now regard as characteristic of the Lower Silurians, might at any time be found to have survived into the Upper Silurian period. We should never forget, therefore, in determining the age of a rock by palæontological evidence alone, that we are always reasoning upon generalisations which are the result of experience alone, and which may at any time be overthrown by fresh discoveries.

Chronological Succession of the Aqueous Rocks.

As the result of observations made upon the superposition of rocks in different localities, from their mineral characters, and from their included fossils, geologists have been able to divide the entire stratified series into a number of different divisions or formations, each characterised by a *general* uniformity of mineral composition, and by a special and peculiar *assemblage* of organic forms. Each of these primary groups is in turn divided into a series of smaller divisions, characterised and distinguished in the same way. It is not pretended for a moment that all these primary rock-groups can anywhere be seen surmounting one another regularly. There is no region upon the earth where all the stratified formations can be seen together; and, even when most of them occur in the same country, they can nowhere be seen all succeeding each other in their regular and uninterrupted succession. The reason of this is obvious. There are many places—to take a single example—where one may see the Silurian Rocks, the Old Red Sandstone, and the Carboniferous Rocks succeeding one an-

other regularly, and in their proper order. This is because the particular region where this occurs was always submerged beneath the sea while these formations were being deposited. There are, however, many more localities in which one would find the Carboniferous Rocks resting unconformably upon the Silurians without the intervention of any strata which could be referred to the Old Red Sandstone. This might arise from one of two causes: 1. The Silurians might have been elevated above the sea immediately after their deposition, so as to form dry land during the whole of the Old Red period, in which case, of course, no strata of the age of the Old Red Sandstone could possibly be deposited. 2. The Old Red Sandstone might have been deposited upon the Silurian, and then the whole might have been elevated above the sea, and subjected to an amount of denudation sufficient to remove the Old Red Sandstone entirely. In this case, when the land was again submerged, the Carboniferous Rocks, or any younger formation, might be deposited directly upon Silurian strata. From one or other of these causes, then, or from subsequent disturbances and denudations, it happens that we can rarely find many of the primary formations following one another consecutively and in their regular order.

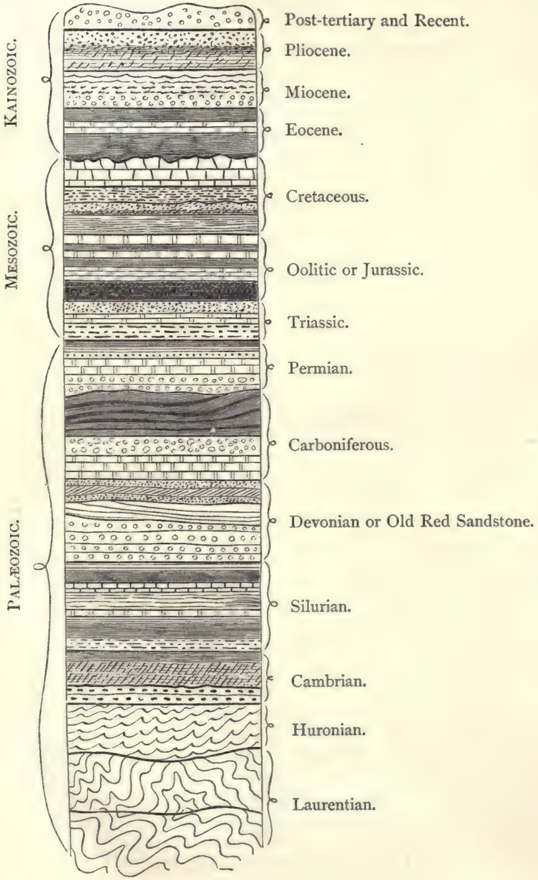
In no case, however, do we ever find the Old Red Sandstone resting upon the Carboniferous, or the Silurian Rocks reposing on the Old Red. We have therefore, by a comparison of many different areas, an established order of succession of the stratified formations, as shown in the subjoined ideal section of the crust of the earth (fig. 2).

The main subdivisions of the Stratified Rocks are known by the following names:—

1. Laurentian.
2. Cambrian (with Huronian?).
3. Silurian.
4. Devonian or Old Red Sandstone.
5. Carboniferous.
6. Permian } New Red Sandstone.
7. Triassic }
8. Jurassic or Oolitic.
9. Cretaceous.
10. Eocene.
11. Miocene.
12. Pliocene.
13. Post-tertiary.

IDEAL SECTION OF THE CRUST OF THE EARTH.

Fig. 2.



Of these primary groups, the Laurentian, Cambrian, Silurian, Devonian, Carboniferous, and Permian are collectively grouped together under the name of *Primary* or *Palæozoic* Rocks (Gr. *palaios*, ancient; *zoe*, life), because of the entire divergence of their animals and plants from any now existing upon the globe. The Triassic, Jurassic, and Cretaceous systems are grouped together as the *Secondary* or *Mesozoic* formations (Gr. *mesos*, intermediate; *zoe*, life), because their organic remains are intermediate between those of the Palæozoic period, and those of more modern strata. The Eocene, Miocene, Pliocene, and Post-tertiary Rocks are grouped together under the head of *Tertiary* or *Kainozoic* Rocks (Gr. *kainos*, new; *zoe*, life), because their organic remains approximate in character to those now existing upon the globe.

CHAPTER III.

CONTEMPORANEITY OF STRATA AND GEOLOGICAL CONTINUITY.

WHEN groups of beds in different parts of the earth's surface, however widely separated from one another, contain the same fossils, or rather an assemblage of fossils in which many identical forms occur, they are ordinarily said to be "contemporaneous;" that is to say, they are ordinarily supposed to belong to the same geological period, and to have been formed at the same time in the history of the earth. They would therefore be unhesitatingly regarded as "geological equivalents," and would be classed as Silurian, Devonian, Carboniferous, and so on. It is to be remembered, however, that it is not necessary, to establish such a degree of equivalency between widely separated groups of strata, that the fossils of each should be to any great extent *specifically* identical. It is sufficient that, whilst some few species are identical in both, the majority of the fossils should be "representative forms," or, in other words, nearly allied species. It will be shown, however, that groups of strata widely removed from one another in point of distance can only exceptionally be "contemporaneous," in the strict sense of this term. On the contrary, in so far as we can judge from the known facts of the present distribution of living beings, the occurrence of exactly the same fossils in beds far removed from one another is *primâ facie* evidence, that the strata are

not exactly contemporaneous, but that they succeeded one another in point of time, though by no long interval geologically speaking.

Most of the facts bearing upon this question may be elicited by a consideration of such a widely extended and well-known formation as the Mountain Limestone or Sub-Carboniferous Limestone. This formation occurs in localities as remote from one another as Europe, Central Asia, North America, South America, and Australia; and it is characterised by an assemblage of well-marked fossils, amongst which *Brachiopods* belonging to the genus *Producta* may be specially singled out. Now, if we believe that the Carboniferous Limestone in all these widely distant localities was strictly contemporaneous, we should be compelled to admit the existence of an ocean embracing all these points, and, in spite of its enormous extent, so uniform in temperature, depth, and the other conditions of marine life, that beings either the same or very nearly the same inhabited it from end to end. We can, however, point to no such uniformity of conditions and consequent uniformity of life over any such vast area at the present day; and we have therefore no right to assume that this is the true explanation of the facts. Indeed, this explanation would almost necessarily lead us to the now abandoned theory that each period in geological history was characterised by a special group of organisms spreading over the whole globe, and that there took place at the close of each period a general destruction of all existing forms of life, and a fresh creation of the new forms characteristic of the next period.

In our inability, then, to accept this view, we must seek for some other explanation of the observed facts. The most probable view, and the one which is supported most strongly both by what we see at the present day and by what we learn from numerous examples in past time, is this:—The Carboniferous Limestone was not deposited all over the world in one given period, by one sea, or at exactly the same time; so that it cannot be said to be strictly "contemporaneous" wherever it is found. This would imply a uniformity of conditions over vast distances, such as exists nowhere at the present day, and such as we have no right to assume ever existed. On the contrary, the deposition of the Carboniferous Limestone must have first taken place in one comparatively limited area—say in Europe—where fitting conditions were present both for the animals which characterise it, and for the formation of beds of its peculiar mineral and physical characters. How wide this area may have been, signifies very little. It may have been as

large as the area now covered by the Pacific, or larger, and yet it could not include all those localities in which strata of Carboniferous age with identical or representative fossils are already known to exist. At the close of the deposition of the Carboniferous Limestone in its original area, the conditions there present must be supposed to have become unsuitable for the further existence in that area of the assemblage of animals which had been its inhabitants, or, at any rate, for a great many of them. The change from suitable to unsuitable conditions must, it is hardly necessary to say, have been an extremely slow and gradual one; and would doubtless be connected with the progressive shallowing of the sea, the diversion of old currents of heated water or the incoming of new currents of cold water, or other physical changes tending to alter the climatic conditions of the area. What, then, would be the effect of such a change of conditions as we have supposed upon the animals inhabiting the area? *a.* Some of them would, doubtless, be sufficiently hardy and accommodating to bear up under the new state of things; and these would persist into the ensuing period, without any perceptible change, it might be, or more probably in the form of varieties or species allied to the old ones. In this case, therefore, we should get a certain number of species which would pass from the Carboniferous Limestone up into the Yoredale Series, the Millstone Grit or the Coal-measures; or, if we did not find any species exactly the same in all these groups, we should still find in the later groups some forms which would be varieties of those of the older, or which would be allied or representative species.

b. There would, in the second place, be a certain number of species which would be utterly unable to withstand the altered conditions of the area; and these would gradually die out and become wholly extinct. We should thus get a certain number of fossils which would be either exclusively confined to the Carboniferous Limestone in general, or which, perhaps, might not be found out of the Carboniferous Limestone of a single region, or even a single particular locality.

c. Lastly, some species would yield so far to the altered conditions of the area that they would "migrate," and seek elsewhere a more congenial home. This term is apt to convey false impressions; and it will be well here to consider what is meant by the "migration" of species or groups of animals. It is quite obvious that only animals like birds, mammals, insects, &c., which enjoy when grown up the power of active locomotion, can actually "migrate" in person, supposing they find themselves placed under unfavourable conditions. There are

many animals, however, such as most shell-fish, corals, sea-urchins, &c., which have, when adult, either no power of changing their place, or at best a very limited one. Still in these cases even, though the *individual* has no means of removing his quarters to some more favoured spot, there may be a "migration" of the *species* from an unsuitable to a suitable locality. This is effected through the medium of the *young*, which have the power of choosing where they will settle, and are endowed with vigorous powers of locomotion. If, for example, a bed of oysters should become placed under conditions unsuitable for the development of these molluscs, it is clear that the old oysters cannot change their location. The young oysters, however, swim about freely; and these will move away from the original bed till they find a place which will suit them. By a repetition of this process there may be in course of time a removal or "migration" of a species to almost any distance, irrespective of the fact that the adult is permanently rooted.

To return, then, to the case which we have been considering:—When the conditions of life in the seas of the Carboniferous Limestone became unfavourable for the further existence of their fauna, some species would migrate to a more congenial area. In this way a greater or less number of the species characteristic of the Carboniferous Limestone would ultimately be transferred to some other area. Here they would mingle with the forms already inhabiting that area, perhaps more or less completely supplanting these, perhaps merely succeeding in maintaining a more or less precarious existence. In either case, their remains would be preserved in the sedimentary deposits of the new area. When, ages afterwards, we come to examine the crust of the earth geologically, we should find these identical and characteristic species of fossils in the rocks of the two areas, and we should say—"these rocks are contemporaneous." It is clear, however, that we should be wrong in so saying. The rocks in question would belong to the same geological period, but they would belong to different stages of the same period, and they would not be strictly contemporaneous. For deposits of this nature, believed to hold this relation to each other, the term of "homotaxeous" has been proposed, in place of the term "contemporaneous."

What has just been said about the Carboniferous Rocks would apply with equal justice to all the great formations, and to many of the smaller rock-groups all over the world. The Silurian Rocks of Europe, North America, South America, Australia, &c., contain very similar fossils, and are undoubtedly "homotaxeous." Nothing, however, that we see at the present

day can justify us in believing that these widely separated deposits are strictly "contemporaneous," in the sense that they were deposited at exactly the same period of time. We should have to believe, if this conclusion is to be justified, that in Silurian times the ocean spread over a much larger area of the earth's surface than it does now, and that its temperature and depth were unnaturally uniform; and there are, perhaps, some who would accept this view. What has been said about the Silurian Rocks as a whole applies with still greater force to certain of the minor subdivisions of the same, which contain many of exactly the same specific forms in parts of the globe very widely removed from one another. It is the very identity of the fossils, however, which proves that the beds in question, from their geographical position, cannot have been deposited at exactly the same time, though they doubtless belong to the same period, and may even be said to be related to one another, as far as the identical fossils are concerned, by lineal descent. Similar remarks might be made about the Devonian, Permian, Triassic, Jurassic, Cretaceous, and other formations; but it is not necessary further to multiply examples.

If we consider the present state of things upon the globe, we shall be further convinced of the justice of these views, which were first prominently brought forward by Professor Huxley. If we could suddenly remove the sea from the earth, we should find at various points of the earth's surface deposits of different kinds, now concealed from us by the ocean, or only partially known by dredgings or soundings. Thus, we should find vast accumulations of calcareous matter, in the form of coral-rock and coral-reef, where now rolls the Pacific Ocean. In high northern and low southern latitudes we should find great deposits of sand and mud, with angular blocks of stone, the whole derived from the ice-clad regions of the poles. Over vast areas, again, in the deep Atlantic, we should find an impalpable chalky mud, or "ooze." All these different deposits are obviously and necessarily "contemporaneous," not only in the geological acceptation of the word, but in its most literal sense. In spite of this fact *they would not contain the same fossils;* and, indeed, they would be characterised by organic remains which would be wholly different in each case. The coral-reefs of the Pacific would be essentially characterised by the abundance of the remains of reef-building corals, though they would also present other tropical forms of life, especially Brachiopods and Echinoderms. The glacial mud of the Polar regions would contain the remains of Arctic molluscs, along with such other animals as delight in severe cold. Lastly, the

ooze of the deep Atlantic would contain innumerable *Foraminifera*, along with siliceous Sponges, Sea-urchins, and Crinoids. We learn, therefore, from this, that contemporaneous deposits not only do not necessarily contain the same fossils, but that, if widely separated geographically, they may be characterised by wholly dissimilar assemblages of organisms.

It may happen, again, as pointed out by Sir Charles Lyell, that deposits belonging to different geographical and zoological provinces may, as regards space, be nearly approximated, and, as regards time, may be actually contemporaneous, and yet may not contain any fossils in common, or only a very few. If, for example, any sudden upheaval were to lay bare what is now the floor of the Red Sea together with that of the Mediterranean, we should find the two areas to contain deposits actually synchronous as regards the time of their deposition, and very near to one another in point of distance, and yet containing, upon the whole, entirely distinct groups of organic remains. We learn, therefore, from this, that owing to the existence of geographical barriers, it is possible for contemporaneous deposits to be found in close contiguity, in a single region, and yet to contain very different fossils.

Again, we know from the researches of Professors Carpenter and Wyville Thomson and Mr Gwyn Jeffreys, that deposits may be formed, side by side, *in a single ocean*, and may yet differ from one another altogether, both in mineral characters and in their included fossils, though strictly contemporaneous in point of time. Thus, in parts of the deep Atlantic where the temperature of the bottom water is comparatively high, we have the calcareous deposit of the ooze, abounding in Foraminifera, Sponges, and Echinoderms. In certain other areas in the same ocean, and in comparatively close contiguity with the preceding, we have the temperature lowered by cold currents, and we find a sandy deposit in process of formation, with a fauna much more scanty than that of the ooze, and wholly distinct from it. We thus learn that sedimentary deposits may be strictly contemporaneous, and may be placed very near to one another in point of distance, and yet may contain very different fossils.

Lastly, synchronous deposits necessarily contain wholly different fossils, if one has been deposited by fresh water, and the other has been laid down in the sea. The fresh-water deposits of one period are obviously contemporaneous with the marine formations of the same period, and they may not be far removed from one another in point of distance, but they must contain altogether different organic remains. The former will

contain remains of the fresh-water and terrestrial animals of the period, and of these only; whilst the latter will principally, if not exclusively, be characterised by the remains of marine forms of life. In this way, there is reason to believe, may be explained the differences between the fossils of the Old Red Sandstone and of the Devonian Rocks, strictly so called. Both are believed to have been deposited in the same geological period, and to be truly "contemporaneous;" but they do not contain the same fossils. This may be readily explained, however, if we suppose the former to represent the fresh-water deposits of the Devonian period, or to have been laid down in an inland sea, whilst the latter is the true marine formation of the same period.

We are now in a position very briefly to discuss the question of what may be called "geological continuity." It has already been stated that the entire series of Fossiliferous or Sedimentary Rocks may be naturally divided into a certain number of definite rock-groups or "formations," each of which is characterised by the possession of a peculiar and characteristic assemblage of fossils, constituting, or rather representing, the "life" of the "period" in which the formation was deposited. The older geologists held, what probably every one would be tempted to think at first, that the close of each formation was characterised by a general destruction of the forms of life of the period, and that the commencement of each new formation was accompanied by the creation of a number of new animals and plants, destined to figure as the characteristic fossils of the same. This theory, however, not only invokes forces and processes which it can in no way account for, but overlooks the fact that most of the great formations are separated by lapses of time, unrepresented perhaps by any deposition of rock, or represented only in some particular area, and yet, perhaps, as great as, or greater than, the whole time occupied in the production of the formation itself.

Nowadays, most geologists hold that there was no such sudden destruction of life at the close of each great geological epoch, and no such creation of fresh forms at the commencement of the next period. On the contrary, they hold that there is a geological "continuity," such as we see in other departments of nature, and that the lines which we draw between the great formations merely mark periods of time in which no rocks were laid down, or the rocks deposited in which are at present unknown to us.

What are we to believe occurred at the close of any great geological period—say, the Cretaceous period? If we reject

the view that the close of the period was marked by a sudden and universal extinction and destruction of the characteristic Cretaceous forms of life, there is only one other view which we can take. Confining our attention solely to those seas of the period of which alone we know enough for safe reasoning, we know that the close of the Cretaceous period in Europe was accompanied, or rather caused, by an upheaval of the Cretaceous area, and an obliteration of the Cretaceous sea. This upheaval was, of course, effected with extreme slowness, or, at any rate, not suddenly, and it must have completely changed the life-conditions or "environment" of the animals which swarmed in the Cretaceous seas. Some of these would doubtless be unable to accommodate themselves to their altered surroundings, and would simply die out. Others, we may presume, would migrate to some more favourable area, and some of these might accomplish their migration without undergoing any change. Most, however, of the forms which migrated, in the process of migration, and by reason of coming into contact with strange neighbours and untried conditions, would probably undergo more or less modification. Ultimately, therefore, many characteristic Cretaceous forms might be transferred to some sea far distant from their original home. Not only so, but some of the transferred species might have suffered so much modification that they would no longer be regarded as specifically identical with the original Cretaceous forms, but would be looked upon simply as allied or "representative" species, though really the lineal descendants of the animals of the Chalk.

It is perfectly clear that the process of rock-deposition which was going on in Europe towards the close of the Cretaceous period was not, and could not be, abolished by the elevation of the European area, and the obliteration of the Cretaceous sea, but was simply *transferred* to some other area. In this particular case, we do not happen to know where the new area of deposition may have been. It is quite certain, however, that in whatever area the Cretaceous animals took refuge, there rocks must have been deposited in course of time, as they are in all seas, though it does not in the least follow that the rocks of this new area should have the smallest likeness in mineral composition to the Cretaceous sediments. If we should at any time discover these rocks, it may pretty safely be predicted what we should find in them in the way of fossils. We should find, namely, some Cretaceous species, probably unchanged; with these there would be forms allied to the Cretaceous species, but differing from them to a greater

or less extent; in addition, there would be a certain proportion of forms of life wholly unknown in the Cretaceous Rocks; and, lastly, there would be a conspicuous absence of certain characteristic species of the Chalk period. In other words, such deposits as we have been speaking of would contain an assemblage of fossils more or less intermediate in character between those of the true Cretaceous period and those of the lowest Tertiary beds (Eocene), which rest upon the Chalk, or they would present an intermixture of Cretaceous with Eocene types. In point of fact, we have fragments of such intermediate deposits (in the Mæstricht beds of Holland, the Pisolitic Limestone of France, the Faxoe Limestone of Denmark, and the Thanet Sands of Britain), and we find in them traces of such an intermixture.

We may pause here to consider how it is that we may never hope to find a complete series of deposits linking on one great formation to another, as, for example, the Chalk to the Eocene Rocks. In the first place, only a limited portion of the earth has as yet been properly examined, and we have therefore no right to expect that we have as yet hit upon the area, or areas, to which the process of rock-forming was transferred at the close of the Cretaceous period proper in Europe. We have, however, the full right to expect that we shall ultimately find formations which will have to be intercalated in point of time between the White Chalk and the Eocene; and, as before said, traces of such are already known to us. In the second place, we have every reason to suppose that many of these intermediate deposits have been destroyed at some period subsequent to their formation by what is technically called "denudation," or, in other words, by the action of rain, rivers, ice, and the sea. In the third place, many of the missing deposits may have been concealed since their formation by the deposition upon them of other newer rocks; or they may be situated in areas which are at present covered by the ocean. Lastly, we must not forget that there may have been times in which great changes in life were actively progressing in areas in which there might be little or no contemporaneous deposition of rock, so that the extreme terms of a series might be preserved to us whilst all the intermediate links might have escaped record.

From these and similar causes, it is almost certain that we shall never be able to point to a complete series of deposits linking one great geological period, such as the Cretaceous, to another, such as the Eocene. Still, we may well have a strong conviction that such deposits must exist, or must have existed,

as memorials of, at any rate, part of the time which elapsed between the close of the one formation and the commencement of the next. Upon any theory of "evolution," at any rate, it is certain that there can be no total break in the great series of the stratified deposits, but that there must have been a complete continuity of life, and a more or less complete continuity of deposition, from the Laurentian period to the present day. There was, and could have been, no such continuity in any one given area; but the chain could never have been snapped at one point and taken up at a wholly different one. The links must have been forged in different places, but the chain, nevertheless, remained unbroken. From this point of view, there would be little impropriety in saying that we are living in the Silurian period; but we could only say so in a very limited sense. While most geologists will readily admit that there must have been such an actual continuity of the great geological periods, from the earliest times up to the present day, it remains certain that we can never dispense with the division of the stratified series into definite rock-groups and life-periods. We can never hope to discover all the lost links of the geological chain, and the great formations will always be separated from one another by more or less evident physical or palæontological breaks, or by both combined. The utmost we can at present do is to arrive at the conviction that the lines of demarcation between the great formations only mark gaps in our knowledge, and that there can be in nature no *hiatus* in the long series of fossiliferous deposits.

The theory of "geological continuity," then, may in practice be carried so far as to be useless, or even injurious to the progress of science. This would seem to be the case with the attempt to show that we "are still living in the Cretaceous period," and that the ooze now forming at the bottom of the deep Atlantic is merely a continuation in point of time of the great and well-known formation of the White Chalk. The points of resemblance by which this is sought to be established are these: 1. The Atlantic ooze or "abyssal mud" is a whitish or grayish-looking mud, containing about sixty per cent of carbonate of lime, with from twenty to thirty per cent of silica, and a variable quantity of alumina. When dry, and especially if consolidated, it may fairly be compared in mineral composition to some varieties of Chalk or to Chalk-marl. 2. The abyssal mud of the Atlantic is to a very large extent composed of the microscopic shells of *Foraminifera*, some of which are specifically identical with Cretaceous forms, whilst White Chalk is known to be very largely composed of the *débris*

of these minute organisms. 3. The ooze contains siliceous sponges, in many respects comparable to the sponges which are so characteristic of the Cretaceous period. 4. The ooze contains Echinoderms, especially Sea-urchins and Crinoids, such as abounded in the Chalk period; whilst one of the latter is related to a Cretaceous type hitherto believed to be extinct. 5. We have reason to believe that the conditions under which the Chalk was formed were very similar to those now present in the Atlantic at great depths.

On the other hand, as pointed out by Sir Charles Lyell and Mr Prestwich, the differences between the Atlantic ooze and and the Chalk are, to say the least of it, quite as weighty as the resemblances, if not more so. Chalk is composed of from eighty to as much as ninety-nine per cent of carbonate of lime, and has therefore a very small proportion of any siliceous or aluminous impurity. Secondly, the occurrence of identical species of *Foraminifera* in the two formations amounts to very little; for it is well known that such lowly organised forms of life have an extraordinary power of persistence, surviving geological changes which are fatal to higher organisms. Lastly, the most characteristic of the Chalk fossils, such as the various forms of *Cephalopoda* and Bivalve Molluscs, are entirely wanting in the Atlantic ooze.

Mr Prestwich concludes that although it is probably true that "some considerable portion of the deep sea-bed of the mid-Atlantic has continued submerged since the period of our Chalk, and although the more adaptable forms of life may have been transmitted in unbroken succession through this channel, the immigration of other and more recent faunas may have so modified the old population that the original Chalk element is of no more importance than is the original British element in our own English people. As well might it have been said in the last century that we were living in the period of the early Britons, because their descendants and language still lingered in Cornwall, as that we are living in the Cretaceous period, because a few Cretaceous forms still linger in the deep Atlantic. Period in Geology must not be confounded with 'system' or 'formation.' The one is only relative, the other definite. A formation is deposited or takes place during a certain time, and that time is *the* period of *the* formation; but *a* geological period may include several formations, and is defined by the preponderance of certain orders, families, or genera, according to the extent of the period spoken of; and the passage of some of the forms into the next geological series does not carry the period with them, any more

than would any particular historical epoch be delayed until the survivors of the preceding one had died out. Period is an arbitrary time-division. The Chalk or the 'London Clay' formations mark definite stratigraphical divisions. We may speak of the period of the London Clay, or we may speak of the Tertiary period. It merely refers to the 'time when' either were in course of construction. The occurrence of Triassic forms in the Jurassic series, of Oolitic forms in the Cretaceous series, and of Cretaceous forms in the Eocene, in no way lessens the independence of each series, although it may sometimes render it difficult to say where one series ceases and the other commences. The land and littoral faunas are necessarily more liable to change than a deep-sea fauna, because an island or part of a continent may be submerged, and all on it destroyed, while the fauna of the adjacent oceans would survive; and as we cannot suppose the elevation of entire ocean-beds at the same time, the maritime fauna of one period must be in part almost necessarily transmitted to the next."

In accordance, therefore, with the principles here laid down, we may conclude that it is not correct to say that we "are living in the Cretaceous period," in any other sense than one might say that we are living in the Silurian period, with this difference, that the Cretaceous period is much nearer to us in point of time than the Silurian, and that we can therefore trace a relationship between certain Cretaceous types and certain living forms that we can not hope to establish in the case of Silurian fossils.

It is to be observed, lastly, that certain classes of animals are always likely to flourish in places and times in which favourable conditions are present, wholly irrespective of any genetic connection between successive faunæ. Thus, the conditions present in the deep Atlantic are such as favour the existence of numerous *Foraminifera*, Sponges, *Echinoderms*, &c. Similar conditions existed in the seas in which the Chalk was deposited; and we need not, therefore, be surprised at the predominance of similar organisms in the Cretaceous period. In the same way, there are portions of the Carboniferous Limestone fairly comparable to the Chalk in mineral characters (making due allowance for difference of age), and containing forms of life which may be regarded as representative of the Cretaceous fauna—such as *Foraminifera*, smooth *Terebratulæ*, Crinoids, and Sea-urchins. The conditions, however, present in the deep Atlantic are not *exactly* similar to those under which the Chalk was deposited, for there are certain great classes,

such as the *Cephalopoda*, which abounded in the Cretaceous seas, but which seem to have no representative in the abyssal mud of the Atlantic.

DOCTRINE OF COLONIES.—It only remains in this connection to consider very briefly the doctrine of "colonies," laid down by M. Barrande, the eminent Bohemian palæontologist. It has been laid down as a law that when once a species disappears it never again makes its appearance in the geological record. This is unquestionably true, so long as we remember that it can only apply to cases in which a species has entirely and totally disappeared from the earth, and that it is often very difficult, or altogether impossible, to obtain evidence as to the exact time at which a given species has thus become actually extinct. There are plenty of cases in which a species seemingly disappears in a particular set of rocks, to reappear in some higher and later set of rocks in the same region, whilst its remains are wanting in all the intermediate deposits of the area. It also often occurs that a species, having disappeared in one region, is found in deposits of a later age in another area. The above-mentioned law, therefore, can obviously only hold good of cases in which a species has definitely and finally become extinct; and this implies an amount of knowledge on our part which we seldom or never possess. M. Barrande, however, has pointed out that there are other cases in which groups of species peculiar to one set of beds may appear in a temporary and sporadic manner in a much earlier set of beds, the two deposits thus characterised being separated by beds containing fossils peculiar to the earlier and older series. Thus, the Upper and Lower Silurian Rocks of Bohemia are characterised by very distinct assemblages of fossils. It is found, however, that the Lower Silurian Rocks contain in places a group of fossils characteristic of the Upper Silurian series. The beds containing this "colony" of Upper Silurian forms are succeeded by strata filled with Lower Silurian fossils; and it is only after several alternations of this kind that the Upper Silurian fauna comes in definitely and generally. These temporary appearances of a later fauna in the midst of an older fauna are termed by M. Barrande "colonies," and he explains their occurrence as follows:—If we suppose the seas of the Bohemian area to have been peopled with Lower Silurian animals at a time when other portions of Europe were covered by a sea containing Upper Silurian animals, and suppose the former area to have been shut off from the latter by a land-barrier, we can readily understand how the "colonies" were produced. If, from any cause, a channel of communication

were opened between the Bohemian area and the general area of Northern Europe, an immigration of species would take place from the latter into the former area. The Upper Silurian species of the latter area would thus be imported, in greater or less numbers, into the midst of the general Lower Silurian fauna of Bohemia, and would be preserved in the Lower Silurian Rocks. If, however, the channel of communication were speedily closed, so that the new-comers could not be constantly reinforced by fresh immigrants, the "colonial" species would die out, and the general Lower Silurian fauna would again reign supreme. A reopening of the channel of communication would allow of a fresh immigration and the formation of a fresh "colony," and the process might be indefinitely repeated. Finally, however, we must suppose that the Bohemian area was permanently thrown open to immigration from the general European area, when the Upper Silurian fauna of the latter would succeed in permanently and completely displacing the old Lower Silurian fauna of the former region. The phenomenon, therefore, of "colonies," may be defined as "the coexistence of two general faunas, which, considered in their entirety, are nevertheless distinct;" and it is to be regarded as merely a case of migration under certain peculiar and exceptional circumstances.

CHAPTER IV.

THE IMPERFECTION OF THE PALÆONTOLOGICAL RECORD.

As has been already pointed out, the series of the stratified formations is an imperfect one, and is likely ever to remain so. The causes of this "imperfection of the geological record," as it has been termed by Darwin, are various; but it is chiefly to be ascribed to our as yet incomplete knowledge of the geology of vast areas of the earth's surface, to denudation, and to the fact that many of the missing groups are buried beneath other deposits, whilst more than half of the superficies of the globe is hidden from us by the waters of the sea. The imperfection of the geological record necessarily implies an equal imperfection of the "palæontological record;" but, in truth, the record of life is far more imperfect than the mere physical series of deposits. As we are here chiefly concerned with the biological

aspect of the question, we may advantageously consider some of the main causes of the numerous breaks and gaps in the palæontological record at some length.

I. Causes of the Absence of Certain Animals in Fossiliferous Deposits.—In the first place, even if the series of the stratified deposits had been preserved to us in its entirety, and we could point to the sedimentary accumulations belonging to every period of the earth's history, there would still be enormous deficiencies in the palæontological record, owing to the differences in the facility with which different animals may be preserved as fossils. This subject is sufficiently important to render it advisable to consider each of the primary groups of the animal kingdom separately from this point of view :—

a. Protozoa.—As regards the sub-kingdom of the *Protozoa*, the entire classes of the *Gregarinidæ* and *Infusorian Animalcules*, from their absence of hard parts, must ever remain unrepresented in a fossil condition. One or two of the latter, however, possess an integumentary covering capable under favourable circumstances of being preserved in rocks of recent age. The *Monera* present no structures capable of fossilisation ; and the same may be said of the *Amœbea*, though one or two of the latter have a carapace which might possibly be preserved. The remaining Rhizopodous orders—viz., the *Foraminifera*, *Radiolaria*, and *Spongida*—almost invariably develop hard structures of lime or flint ; and all these orders, therefore, have left abundant traces of their existence in past time.

b. Cœlenterata. — Amongst the Cœlenterate animals, the Fresh-water Polypes (*Hydra*), the Oceanic Hydrozoa, the Jellyfishes (*Medusidæ*), the Sea-blubbers (*Lucernarida*), the Sea-anemones (*Actinidæ*), and the *Ctenophora* are destitute of hard parts which could be preserved as fossils. The Sea-blubbers, however, supply us with an instance of how a completely soft-bodied creature may leave traces of its past existence; for there is no doubt that impressions left by the stranded carcasses of these animals have been detected in certain fine-grained rocks (the Lithographic Slate of Solenhofen). On the other hand, the coralligenous Zoophytes or "corals" (comprising the *Zoantharia sclerodermata* and *sclerobasica*, and most of the *Alcyonaria*) possess hard parts capable of preservation, and the same is the case with most of the Hydroid Zoophytes. Accordingly, there are few more abundant fossils than corals ; whilst the large extinct group of the *Graptolites* is generally placed in the vicinity of the Sea-firs (Sertularians).

c. Annuloida.—In this sub-kingdom the great class of the *Echinodermata* may be said to be represented more or less

completely by all its orders. In the Sea-cucumbers (*Holothuroidea*), however, the calcareous structures so characteristic of the integuments of the other Echinoderms are reduced to their minimum; and accordingly the evidence of the past existence of these creatures is of the most scanty description. The other great class of the *Annuloida* (viz., the *Scolecida*) comprises animals almost without exception destitute of hard parts, and which mostly live parasitically in the interior of other animals (*e.g.*, the Tape-worms, Suctorial-worms, Round-worms, &c.) We are therefore without any geological evidence of the former existence of *Scolecida*, though no doubt can be reasonably entertained but that the group dates back to a time long anterior to the present fauna.

d. Annulosa.—Many of the lower Annulose animals, such as Leeches, Earth-worms, and Errant Annelides, possess no structures by which we could expect to get direct evidence of their past existence. The last of these, however, have left ample traces of their former presence in the form of burrows or "tracks" upon the mud and sand of ancient sea-bottoms; and the so-called "Tubicolar" Annelides are well represented by their investing tubes. In the case of the higher *Annulosa*, another law steps in to regulate their comparative abundance as fossils. Most, in fact almost all, fossiliferous formations have been deposited in water; and of necessity, therefore, most fossils are the remains of animals whose habits are naturally aquatic. As most deposits, further, are not only aqueous, but are also marine, most fossils are those of sea-animals. It follows, therefore, that the remains of air-breathing animals, whether these be terrestrial or aerial, can only be preserved in an accidental manner, so to speak; except the animal inhabit water (as the Cetaceans do), or except in the rare instances in which old land-surfaces have been buried up by sediment, and thus partially kept for our inspection. In accordance with this law, the most important and abundant fossil Annulose animals are *Crustaceans;* since these not only have a resisting shell or "exoskeleton," but are also generally aquatic in their habits. The air-breathing classes of the *Myriapoda* (Centipedes and Millipedes), the *Arachnida* (Spiders and Scorpions), and the *Insecta* or true Insects, on the other hand, have been much less commonly and completely preserved, though many of them are perfectly capable of being fossilised. Almost all such remains, however, as we have of these three great classes, are the remains of isolated individuals, which may have been accidentally drowned; or else they occur in hollow trees, or in fragments of ancient soils, or in vegetable accumulations such

as coal and peat. There is, however, a considerable number of aquatic insects (but exclusively in fresh water), and there are many insects the larvæ of which inhabit water, whether this be fresh or salt; so that instances of these occurring as fossils are not very infrequent.

e. Mollusca.—This sub-kingdom requires little notice, since the greater number of its members possess hard structures capable of being preserved in a fossil condition. Thus, the horny or calcareous polypidoms of many of the *Polyzoa*, the shells of the Brachiopods, the true Bivalves, and most of the *Gasteropoda*, the internal skeletons of the Cuttle-fishes, and the chambered shells of the Tetrabranchiate Cephalopods, all occur more or less abundantly as fossils. The entire class of the Tunicaries, however, presents (with one or two exceptions) no hard structures, and is hence not with certainty known by any fossil representative. Amongst the *Gasteropoda*, again, the Sea-slugs and their allies (*Nudibranchiata*) possess no shell, and are unknown to the palæontologist; whilst the shell of the Land-slugs is extremely minute, and has not been certainly recognised as fossil. Lastly, the air-breathing terrestrial Molluscs, from their habits, rarely occur as fossils; whilst those which inhabit rivers, ponds, and lakes are less largely represented than marine forms, owing to the preponderance of salt-water deposits over those of fresh water.

f. Vertebrata.—The majority of Vetebrate animals possess a bony skeleton, so that their preservation in a fossil state—so far as this point is concerned—is attended with no difficulty. Some of the fishes, however (such as the Lancelet, the Hag-fishes, and the Lampreys), have no scales, and either possess no "endoskeleton" or have one which is almost wholly cartilaginous. The only evidence, therefore, which could be obtained of the past existence of such fishes would be afforded by their teeth; but these are wanting in the Lancelet, and are very small in the Lampreys: so that we need not wonder that these fishes are unknown as fossils. The higher groups of the fishes, however, taking everything into consideration, may be said to be abundantly represented in a fossil condition by their scales, bones, teeth, and defensive spines.

The Amphibians are tolerably well represented by their bones and teeth, and, as regards one extinct order, by integumentary plates as well. They have also left many traces of their existence in the form of footprints. Most living Amphibians, however, frequent fresh waters, or spend a great part of their time upon the land; and hence their remains would not be apt to be preserved in marine deposits.

The abundance of Reptiles as fossils naturally varies much, according to the habits of the different orders. Of the living orders, the Chelonians (Tortoises and Turtles) are by no means rare; since many of them are habitual denizens of fresh water or of the sea, whilst all are provided with a hard integumentary skeleton. The Snakes are mainly represented by forms which frequented water, and especially by marine forms. The Lizards (*Lacertilia*) live mainly upon the land, and do not therefore abound as fossils; but some extinct forms (the Mosasauroids) were marine in their habits, and have consequently been pretty fully preserved. The *Crocodilia*, again, are so essentially aquatic in their habits, that their comparative frequency in aqueous deposits is no matter of wonder, especially if we recollect that many of the extinct members of this order seem to have frequented the sea itself. Of the extinct orders of Reptiles, the great *Ichthyosauri* and the *Plesiosauri* and their allies were marine in their habits, and their remains occur in what may fairly be called profusion. The Flying Reptiles, or *Pterodactyles*, would not seem to have any better chance of being preserved than Birds, if as good, yet their remains occur by no means very rarely in certain formations. The terrestrial *Deinosaurs* and *Dicynodonts*, again, come very much under the laws which regulate the preservation of Mammals as fossils; and their remains are chiefly, but not exclusively, to be found in fluviatile deposits.

As regards Birds, their powers of flight, as pointed out by Sir Charles Lyell, would save them from many destructive agencies, and the lightness of their bones would favour the long floating of the body in water, and thus increase the chances of its being devoured by predaceous animals. In accordance with these considerations the most abundant remains of Birds are referable to large wingless forms, to which the power of saving themselves from their enemies by flight was denied, whilst most of their bones were filled with marrow instead of air. Next in abundance after these come the remains of birds which frequent the sea-shore, lakes, estuaries, or rivers, or which delight in marshy situations.

Lastly, as regards Mammals, the record is far from being a full one, and from obvious causes. The great majority of Mammals live on land, and therefore are not likely to be buried in aqueous, and especially in marine, accumulations. That this cause is the chief one which has operated against the frequent preservation of Mammalian remains is shown by the fact that when we exhume an old land-surface, the remains of Mammals may be found in tolerable plenty. The strictly

aquatic Mammals—such as Whales, Dolphins, and the like—are, of course, much more likely to have been preserved as fossils than the strictly terrestrial forms; but their want of integumentary hard structures places them at a disadvantage in this respect as compared with fishes. In a general way, we may conclude that the preservation of the terrestrial Mammals as fossils is due to the comparatively rare occurrence of a stray individual being killed whilst swimming a river or some other piece of water, or being mired in a bog, or to the bones of one that had died on land being washed into some stream by floods; but there are other cases for which a different explanation must be sought.

II. UNREPRESENTED TIME.—In the second place, we have seen that the *geological* record is very imperfect, and this of necessity causes vast gaps in our palæontological knowledge. In this connection we may briefly consider the evidence which we possess as to the immensity of the "unrepresented time" between some of the great formations, and no better example can be chosen than that of the Cretaceous and Eocene Rocks. In considering such a case, the evidence may be divided into two heads, the one palæontological, the other purely physical, and each may be looked at separately.

The Chalk, as is well known, constitutes in Britain the highest member of the Cretaceous formation, and is the highest deposit there known as appertaining to the great Secondary or Mesozoic series. It is directly overlaid in various places by strata of Eocene age, which form the base of the great Tertiary or Kainozoic series of rocks. The question, then, before us is this, What evidence have we as to the lapse of time represented merely by the dividing-line between the highest beds of the Chalk and the lowest beds of the Eocene?

Taking the palæontological evidence first, it is found that out of five hundred species of fossils known in the Upper Cretaceous beds, only one *Brachiopod* and a few *Foraminifera* have hitherto been detected in the immediately overlying Eocene beds. These latter, on the contrary, are replete with organic remains wholly distinct from those of the Cretaceous beds. It may be said, therefore, that the very extensive assemblage of animals which lived in the later Cretaceous seas of Britain had entirely passed away and become a thing of the past, before a single grain of the Eocene Rocks had been deposited. Now, it is of course open to us to believe that the animals of the Chalk sea were suddenly extinguished by some natural agencies unknown to us, and that the animals of the Eocene sea had been in as sudden and as obscure a manner

introduced *en masse* into the same waters. This theory, however, calls upon the stage forces of which we know nothing, and is contradicted by the whole tenor of the operations which we see going on around us at the present day. It is preferable, therefore, to believe that no such violent processes of destruction and re-peopling took place, but that the marked break in the life of the two periods indicates an enormous lapse of time. The Cretaceous animals, in consequence of the elevation of the British area at the close of the Cretaceous period, must have mostly migrated, some doubtless perishing, and others probably becoming modified in the process. When the British area became once more submerged beneath the sea, and became again a fitting home for marine life, an immigration into it would set in from neighbouring seas. By this time, however, the Cretaceous animals must have mostly died out, or must have become greatly changed in their characters; and the new immigrants would be forms characteristic of the Lower Eocene. How long the processes here described may have taken, it is utterly impossible to say, even approximately. Judging, however, from what we can observe at the present day, the palæontological break between the Chalk and the Eocene indicates a perfectly incalculable lapse of time; for all species change or die out slowly, marine species especially so; and we have here the disappearance of a large fauna almost in its entirety, and its replacement by another wholly distinct.

In the second place, to come to the physical evidence, the Eocene strata are seen to rest upon an eroded and denuded surface of Chalk, filling up "pipes" and winding hollows which descend far below the general surface of the latter. Not only so, but the base of the Eocene Rocks is commonly composed of a bed of rolled and rounded flints, derived from the Chalk, affording incontestable proof that the Chalk had been greatly worn down and removed by denudation, before the Eocene beds were deposited upon its surface. In short, the Eocene Rocks repose "unconformably" upon the Chalk, and this, as is well known, indicates the following series of phenomena:—Firstly, the Chalk was deposited in horizontal layers at the bottom of the Cretaceous sea. Secondly, at some wholly indefinite time after its deposition, after it had become more or less consolidated, the Chalk must have been raised by a gradual process of elevation above the level of the sea, during which it would inevitably suffer vast denudation. Thirdly, after another wholly indefinite period, the Chalk was again submerged beneath the sea, in which process it would be subjected to still further denudation, and an approximately level

surface would be formed upon it. Fourthly, strata of Eocene age were deposited upon the denuded surface of the Chalk, filling up all the hollows and inequalities of its eroded surface (fig. 3).

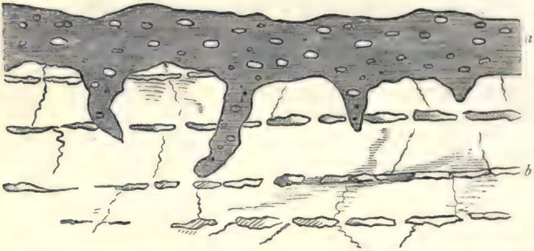


Fig. 3.—Section showing strata of Tertiary age (*a*), resting upon a worn and denuded surface of White Chalk (*b*), the stratification of which is marked by lines of flints.

In the unconformability, then, between the Chalk and the Eocene Rocks, we have unequivocal evidence—irrespective of anything that we learn from Palæontology—that the break between the two formations was one of enormous length. In Britain the interval of time thus indicated is not represented by any deposits; and in Europe generally there are but fragmentary traces of such. We may be quite sure, however, that during the time represented in Britain by the mere line of unconformability between the Chalk and the Eocene, there were somewhere deposited considerable accumulations of sediment. Whether we shall ever succeed in discovering these, or any part of these, is, of course, uncertain. We may be certain, however, that such deposits, if ever discovered, will prove to be charged with the remains of animals more or less intermediate in character between those of the Cretaceous and those of the Eocene period; and the huge gap now existing between these formations will thus be more or less completely bridged over.

Amongst other well-known instances of more or less general unconformity in the stratified series, may be mentioned that between the Lower and Upper Silurian (not always present), that between the Lower and Upper Old Red Sandstone (also not universal), that between the Carboniferous and Permian Rocks, that between the Permian and Triassic Rocks (not universal), and that between the Lower and Upper Cretaceous

Rocks. All these physical breaks are accompanied by more or less extensive palæontological breaks as well. Other breaks which are rendered less important by the absence or scarcity of fossils, or which are as yet not thoroughly established, are those between the Lower and Upper Laurentian Rocks, the Upper Laurentian and Huronian, and the Upper Cambrian and Lower Silurian.

It may not be out of place to point out that the unconformabilities here indicated must in no way be confounded with the common cases in which beds of one age rest unconformably upon beds far older than themselves. When, for example, we find beds of Carboniferous age reposing unconformably upon Silurian strata, this merely indicates that, in the particular locality under examination, the Devonian or Old Red Sandstone is amissing. This absence of a whole formation in any given region merely indicates that the area was dry land during the period of that formation, or that if any rocks of this age were deposited in this locality, they were removed by denudation before the higher group was laid down. The instances above spoken of, as where the Carboniferous Rocks are succeeded unconformably by the Permian, though essentially of the same nature, are distinguished by an important point. In the former case we know what formation is wanting, and we can intercalate it from foreign areas, and thus complete the series. In the latter case we have two successive formations in unconformable junction, and we are not acquainted with any intermediate group of strata which could be intercalated from any other locality.

From the above facts, then, we learn that one of the chief causes of the imperfection of the palæontological record is to be found in the vast spaces of time which separate most of the great "formations," and which, so far as we yet know, are not represented by any formation of rock. In process of time we shall doubtless succeed in finding deposits to account for more or less of this "unrepresented time," but much will ever remain for which we cannot hope to find the representative sediments. It only remains to add that we have ample evidence within the limits of each formation, and wholly irrespective of any want of conformity, of such lengthened pauses in the work of deposition as to have allowed of great zoological changes in the interim, and to have thus caused irremediable blanks in the palæontological record. The work of rock-deposition is at best an intermittent process; the changes in a fauna, if slowly effected, are continuous. Thus there are scores of instances in which the fauna of a given bed, perhaps but a few inches in

thickness, differs altogether from that of the beds immediately above and below, and is characterised by species peculiar to itself. In such cases we can only suppose, that though no physical break can be detected, the deposition of sediment was interrupted by pauses of incalculable length, during which no additional material was added to the sea-bottom, whilst time was allowed for the dying out of old species and the coming in of new. The incessant repetition of such intervals of unrepresented time throughout the whole stratified series is convincing proof that the palæontological record is, and ever must be, a mere excerpt from the biological annals of the globe.

III. Thinning out of Beds.—Another cause by which the continuity of the palæontological record is affected is what is technically called the "thinning out" of beds. Owing to the mode in which sedimentary rocks are produced, it is certain that there must be for every bed a point whence the largest amount of sediment was derived, and in the neighbourhood of which the bed will therefore be thickest. Thus, if we take a series of beds, such as sandstones and conglomerates, which are the product of littoral action, and are deposited in shallow water near a coast-line, it will be found that these gradually decrease in thickness, or "thin out," as we pass away from the coast in the direction of deep water. On approaching deep water, however, we might find that, though the sandstones were rapidly dying out, the thickness of the entire series might still be preserved, owing to the commencement now of some deep-water deposit, such as limestone. The beds of limestone

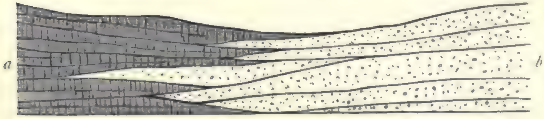


Fig. 4.—Diagram to show the "thinning out" of beds. *a* Sandstones and Conglomerates; *b* Limestones.

would at first be very thin, but in proceeding still in the direction of deeper water, we should find that they would gradually expand, till they reached a point of maximum thickness, on the other side of which they would gradually thin out. Each individual bed, therefore, in any group of stratified rocks, may be regarded as an unequal mass, thickest in the centre, and gradually tapering off or "thinning out" in all directions towards the circumference (fig. 4).

In a general way this holds good, not only for any particular bed, but for any particular aggregation or group of beds which we may choose to take. In the case, namely, of every group of beds, there must have been a particular point whither sediment was most abundantly conveyed, or where the other conditions of accumulation were especially favourable. At this point, therefore, the beds are thickest, and from this they thin out in all directions. It need scarcely be pointed out, indeed, that some such state of things is unavoidable in the case of every bed or group of beds, since no sea is boundless, and the sedimentary deposits of every ocean must come to an end somewhere.

An excellent example of the phenomena above described may be derived from the Lower Carboniferous Rocks of Britain. Here we may start in South Wales and in Central England with the Carboniferous Limestone as a great calcareous mass over 1000 feet in thickness, and almost without a single intercalated layer of shale. Passing northwards, some of the beds of limestone begin to thin out, and their place is taken by strata of a different mineral nature, such as sandstone, grit, or shale. The result of this is, that by the time we have followed the Carboniferous Limestone into Yorkshire and Westmoreland, in place of a single great mass of limestone, we have an equivalent mass of alternating strata of limestone, sandstone, grit, and shale, with one or two thin seams of coal—the limestones, however, still bearing a considerable proportion to the whole. Passing still further northwards, the limestones go on thinning out, till in Central Scotland, in place of the dense calcareous accumulations of Derbyshire, the Lower Carboniferous series consists of a great group of sandstones, grits, and shales, with thick and workable beds of coal, and with but few and comparatively insignificant beds of limestone.

The state of things indicated by these phenomena is as follows:—The sea in which the Lower Carboniferous Rocks of Britain were deposited must have gradually deepened from north to south. The land and coast-line whence the coarser mechanical sediments were derived, must have been placed somewhere to the north of Scotland, and the deepest part of the ocean must have been somewhere about Derbyshire. Here the conditions for lime-making were most favourable, and here consequently we find the greatest thickness of calcareous strata, and the smallest intermixture of mechanical deposits.

The palæontological results of this are readily deducible. The entire Lower Carboniferous series of Britain was probably deposited in a single ocean, apparently destitute of land-bar-

riers; and consequently, taken as a whole, the fauna of this series may be regarded as one and indivisible. The conditions, nevertheless, which obtained in different parts of this area were very different; and, as a necessary result, certain groups of animals flourished in certain localities, and were absent or but scantily represented in others. In the deeper parts of the area we have an abundance of Corals, with Crinoids, and at times *Foraminifera*. In the shallower parts of the area there is, on the other hand, a predominance of forms which affect water of no great depth. Still, there is no difference in point of time between the deposits of different parts of the area; and in order to obtain a true notion of the Lower Carboniferous fauna, we must add the fossils derived from one portion of the area to those derived from another.

In many cases, however, we are acquainted with but one class of deposits belonging to a given period. We may have the deep-sea deposits of the period only, or we may know nothing but its littoral accumulations. In either case it is clear that there is an imperfection of the palæontological record; for we cannot have even a moderately complete record of the marine animals alone of a particular period, unless we have access to a complete series of the deposits laid down in the seas of that period.

IV. Sudden Extinction of Animals.—Whilst there can be little doubt but that the changes in animal life indicated by Geology were in the main gradually effected, there still remain cases in which individuals seem to have been suddenly destroyed in great numbers, and others of a more obscure nature in which allied species succeed one another with an inexplicable rapidity. As an example of the first class of cases, we may take the great Marine Reptiles of the Lias, which often exhibit indications of having met a sudden death, whilst they show no traces of mechanical injury. It has been suggested by Sir Charles Lyell, with great probability, that the sudden death of marine animals, in these and other similar cases, might have been caused by the sudden "periodical discharge of large bodies of turbid fresh water into the sea."

As an example of the second class of cases—which more especially bear upon the present question—we may take the existence in the Lias of zones characterised by particular species of Ammonites. These zones are usually of small thickness, and the Ammonite characterising each is usually confined to that particular horizon; whilst several of these zones have been found to be persistent over very wide areas. As we know of no reason why one species of Ammonite should flourish where

another allied species would not, we cannot at present account for this sudden disappearance of one species and its seeming immediate replacement by another. We may be sure, however, that we have here an imperfection of the palæontological record, and that in reality any two zones must have been separated by a long period, in which one species became extinct, or was so far modified as to appear as a new species.

V. Disappearance of Fossils.—The last subject which need be mentioned in connection with the imperfection of the palæontological record is that of the disappearance of fossils from rocks originally fossiliferous. This, as a rule, is due to "metamorphism"—that is to say, the subjection of the rock to a sufficient amount of heat to cause a rearrangement of its particles. When of at all a pronounced character, the result of metamorphism is invariably the obliteration of any fossils which might have been originally present in the rock. To this cause must be set down many great gaps in the palæontological record, and the irreparable loss of much fossil evidence. The most striking example which is to be found of this is the great Laurentian series, which comprises some 30,000 feet of highly metamorphosed sediments, but which, with one not absolutely certain exception, has as yet yielded no remains of life, though there is strong evidence of the former existence in it of fossils.

Another not uncommon cause of the disappearance of organic remains from originally fossiliferous deposits is the percolation through them of water holding carbonic acid in solution. By this means fossils of a calcareous nature are dissolved out of the rock, and may leave no traces behind. This cause, however, can only operate to any extent in more or less loose and porous arenaceous deposits.

Lastly, "cleavage" may be mentioned as a common cause of the disappearance of fossils. The cleavage, however, must be very intense, if it actually prevents the recognition of the deposit as one in which fossils formerly existed, though cases are not uncommon in which this occurs through thousands of feet of strata. As a more general rule, however, it is not very difficult to determine whether a cleaved rock has ever contained fossils or not, though it may be quite impossible to make out the exact nature and character of the organic remains.

CHAPTER V.

CONCLUSIONS TO BE DRAWN FROM FOSSILS.

We have already seen that geologists have been led by the study of fossils to the all-important generalisation that the vast series of the Fossiliferous or Sedimentary Rocks may be divided into a number of definite groups or "formations," each of which is characterised by its organic remains. It may simply be repeated here that these formations are not properly and strictly characterised by the occurrence in them of any one particular fossil. It may be that a formation contains some particular fossil, or fossils, not occurring out of that formation, and that in this way an observer may identify a given group with tolerable certainty. It very often happens, indeed, that some particular stratum, or sub-group of a series, contains peculiar fossils, by which its existence may be determined in various localities. As before remarked, however, the great formations are characterised properly by the association of certain fossils, by the predominance of certain families or orders, or by an *assemblage* of fossil remains representing the "life" of the period in which the formation was deposited.

Fossils, then, enable us to determine the *age* of the deposits in which they occur. Fossils further enable us to come to very important conclusions as to the mode in which the fossiliferous bed was deposited, and thus as to the condition of the particular district or region occupied by the fossiliferous bed at the time of the formation of the latter. If, in the first place, the bed contain the remains of animals such as now inhabit rivers, we know that it is "fluviatile" in its origin, and that it must at one time have either formed an actual river-bed, or been deposited by the overflowing of an ancient stream. Secondly, if the bed contain the remains of shell-fish, minute crustaceans, or fish, such as now inhabit lakes, we know that it is "lacustrine," and was deposited beneath the waters of a former lake. Thirdly, if the bed contain the remains of animals such as now people the ocean, we know that it is "marine" in its origin, and that it is a fragment of an old sea-bottom.

We can, however, often determine the conditions under which a bed was deposited with greater accuracy than this. If, for example, the fossils are of kinds resembling the marine animals now inhabiting shallow waters, if they are accompanied by the detached relics of terrestrial organisms, or if they are partially rolled and broken, we may conclude that the fossili-

ferous deposit was laid down in a shallow sea, in the immediate vicinity of a coast-line, or as an actual shore-deposit. If, again, the remains are those of animals such as now live in the deeper parts of the ocean, and there is a very sparing intermixture of extraneous fossils (such as the bones of birds or quadrupeds, or the remains of plants), we may presume that the deposit is one of deep water. In other cases, we may find, scattered through the rock, and still in their natural position, the valves of shells such as we know at the present day as living buried in the sand or mud of the sea-shore or of estuaries. In other cases, the bed may obviously have been an ancient coral-reef, or an accumulation of social shells, like Oysters. Lastly, if we find the deposit to contain the remains of marine shells, but that these are dwarfed of their fair proportions and distorted in figure, we may conclude that it was laid down in a brackish sea, such as the Baltic, in which the proper saltness was wanting, owing to its receiving an excessive supply of fresh water.

In the preceding, we have been dealing simply with the remains of aquatic animals, and we have seen that certain conclusions can be accurately reached by an examination of these. As regards the determination of the conditions of deposition from the remains of aerial and terrestrial animals, or from plants, there is not such an absolute certainty. The remains of land-animals would, of course, occur in "sub-aerial" deposits —that is, in beds, like blown sand, accumulated upon the land. Most of the remains of land-animals, however, are found in deposits which have been laid down in water, and they owe their present position to having been drowned in rivers or lakes, or carried out to sea by streams. Birds, Flying Reptiles, and Flying Mammals might also similarly find their way into aqueous deposits; but it is to be remembered that many birds and mammals habitually spend a great part of their time in the water, and that these might therefore be naturally expected to present themselves as fossils in Sedimentary Rocks. Plants, again, even when undoubtedly such as must have grown on land, do not prove that the bed in which they occur was formed on land. Many of the remains of plants known to us are extraneous to the bed in which they are now found, having reached their present site by falling into lakes or rivers, or being carried out to sea by floods or gales of wind. There are, however, many cases in which plants have undoubtedly grown on the very spot where we now find them. Thus it is now generally admitted that the great coal-fields of the Carboniferous age are the result of the growth *in situ* of the plants which compose coal, and that these grew on vast

marshy or partially submerged tracts of level alluvial land. We have, however, distinct evidence of old land-surfaces, both in the Coal-measures and in other cases (as, for instance, in the well-known "dirt-bed" of the Purbeck series). When, for example, we find the erect stumps of trees standing at right angles to the surrounding strata, we know that the surface through which these send their roots was at one time the surface of the dry land, or, in other words, was an ancient soil (fig. 5).

Fig. 5.—Erect Tree containing Reptilian remains. Coal-measures, Nova Scotia (after Dawson).

CONCLUSIONS AS TO CLIMATE.—In many cases fossils enable us to come to important conclusions as to the climate of the period in which they lived, but only a few instances of this can be here adduced. As fossils in the majority of instances are the remains of marine animals, it is mostly the temperature of the sea which can alone be determined in this way; and it is important to remember that, owing to the existence of heated currents, the marine climate of a given area does not necessarily imply a correspondingly warm climate in the neighbouring land. Land-climates can only be determined by the remains of land-animals or land-plants, and these are comparatively rare as fossils. It is also important to remember that all conclusions on this head are really based upon the present distribution of animal and vegetable life on the globe, and are therefore liable to be vitiated by the following considerations:—

a. Most fossils are extinct, and it is not certain that the habits and requirements of any extinct animal were exactly similar to, or even at all resembling, those of its nearest living relative.

b. When we get very far back in time, we meet with groups of organisms so unlike anything we know at the present day as to render all conjectures as to climate founded upon their supposed habits more or less uncertain and unsafe.

c. In the case of marine animals, we are as yet very far from knowing the exact limits of distribution of many species within our present seas; so that conclusions drawn from living forms as to extinct species are apt to prove incorrect. For instance, it has recently been shown that many shells formerly believed to be confined to the Arctic Seas have, by reason of the extension of Polar currents, a wide range to the south; and this has thrown doubt upon the conclusions drawn from fossil shells as to the Arctic conditions under which certain beds were supposed to have been deposited.

d. The distribution of animals at the present day is certainly dependent upon other conditions beside climate alone; and the causes which now limit the range of given animals are certainly such as belong to the existing order of things. But the establishment of the present order of things does not date back in many cases to the introduction of the present species of animals. Even in the case, therefore, of existing species of animals, it can often be shown that the past distribution of the species was different formerly to what it is now, not necessarily because the climate has changed, but because of the alteration of other conditions essential to the life of the species or conducing to its extension.

Still, we are in many cases able to draw completely reliable conclusions as to the climate of a given geological period, by an examination of the fossils belonging to that period. Among the more striking examples of how the past climate of a region may be deduced from the study of the organic remains contained in its rocks, the following may be mentioned: It has been shown that in Eocene times, or at the commencement of the Tertiary period, the climate of what is now Western Europe was of a tropical or sub-tropical character. Thus the Eocene beds are found to contain the remains of shells such as now inhabit tropical seas, as, for example, Cowries and Volutes; and with these are the fruits of palms, and the remains of other tropical plants. It has been shown, again, that in Miocene times, or about the middle of the Tertiary period, Central Europe was peopled with a luxuriant flora resembling that of the warmer parts of the United States, and leading to the conclusion that the mean annual temperature must have been at least 30° hotter than it is at present. It has been shown that, at the same time, Greenland, now buried beneath a vast ice-shroud, was warm enough to support a large number of trees, shrubs, and other plants, such as inhabit the temperate regions of the globe. Lastly, it has been shown, upon physical as well as palæontological evidence, that the

greater part of the North Temperate Zone, at a comparatively recent geological period, has been visited with all the rigours of an Arctic climate, resembling that of Greenland at the present day. This is indicated by the occurrence of Arctic shells in the superficial deposits of this period, whilst the Musk-ox and the Reindeer roamed far south of their present limits.

CHAPTER VI.

DIVISIONS OF THE ANIMAL KINGDOM, AND SUCCESSION OF ORGANIC TYPES.

It seems hardly necessary to remark that Palæontology, as a science, is based upon the kindred sciences of Zoology and Botany, and that no satisfactory acquaintance with the former can be arrived at without the previous acquisition of some knowledge of the latter. It cannot be pretended to teach here even the rudiments of these sciences, but there are a few points which may be noticed as having a special bearing upon the study of Palæontology.

Classification of the Animal Kingdom.—Leaving the vegetable kingdom till we come to speak of fossil plants, a few remarks may be made on the classification of the animal kingdom. Vast as is the number of known animals, all, whether living or extinct, may be classed under some five or six primary divisions or "morphological types," which are technically spoken of as the "sub-kingdoms." All the animals in any one sub-kingdom agree with one another in their structural type, or in the fundamental plan upon which they are constructed; and they differ from one another simply in the modifications of this common plan. No comparison, therefore, is possible between an animal belonging to one sub-kingdom, and one belonging to another, since their distinguishing characters are the result of the modification of two essentially different ground-plans. Hence, it is possible to arrange the animals of any one sub-kingdom in something like a linear series, in which the lowest of the series most closely approaches the primitive or ideal form of the sub-kingdom, whilst the highest exhibits the greatest amount of complexity and specialisation of this type. But it is not possible to establish any such linear classification for the animal kingdom as a whole. Given an animal of a lower "sub-kingdom" than another

animal, no amount of complexity, no specialisation of organisation, can raise the former above the latter. The one may be the result of the high evolution of a low morphological type, the other may be the result of the low evolution of a higher morphological type, but the superiority of the ground-plan gives the latter the higher place. We must therefore abandon the idea that it is possible to establish a linear classification of the animal kingdom.

The following synoptical table gives briefly the leading divisions of the animal kingdom, and the chief characters of these :—

TABULAR VIEW OF THE CHIEF DIVISIONS OF THE ANIMAL KINGDOM.

INVERTEBRATE ANIMALS.

SUB-KINGDOM I.—PROTOZOA.

Animal simple or forming colonies, usually very minute ; the body composed of the structureless, jelly-like, albuminous substance called "sarcode;" not divided into regular segments ; having no nervous system ; no regular circulatory system ; usually no mouth ; no definite body-cavity or digestive system, or at most but a short gullet.

CLASS A. GREGARINIDÆ.—Minute Protozoa which inhabit the interior of insects and other animals, and which have not the power of throwing out prolongations of their substance (pseudopodia). No mouth.

CLASS B. RHIZOPODA (Root-footed Protozoa).—Protozoa which are simple or compound, and have the power of throwing out and retracting prolongations of the body-substance (the so-called "pseudopodia"). No mouth, in most, if not in all.

Order 1. *Monera.—Ex.* Protogenes.

Order 2. *Amœbea.—Ex.* Proteus Animalcule (Amœba).

Order 3. *Foraminifera.—Ex.* Lagena, Nodosaria, Globigerina.

Order 4. *Radiolaria.—Ex.* Thalassicolla, Polycystina.

Order 5. *Spongida.—Ex.* Fresh-water Sponge (Spongilla), Venus's Flower-Basket (Euplectella).

CLASS C. INFUSORIA (Infusorian Animalcules).—Protozoa with a mouth and short gullet ; destitute of the power of emitting pseudopodia ; furnished with vibratile cilia or contractile filaments ; the body usually composed of three distinct layers.

Order 1. *Ciliata.—Ex.* Bell-animalcule (Vorticella), Paramœcium.

Order 2. *Flagellata.—Ex.* Peranema.

Order 3. *Suctoria.—Ex.* Podophyra.

SUB-KINGDOM II.—CŒLENTERATA.

Animals whose alimentary canal communicates freely with the general cavity of the body; body composed essentially of two layers or membranes, an outer layer or "ectoderm," and an inner layer or "endoderm." No circulatory system or heart, and in most no nervous system. Skin furnished with minute stinging organs or "thread-cells." Distinct reproductive organs in all.

CLASS A. HYDROZOA.—Walls of the digestive sac not separated from

those of the general body-cavity, the two coinciding with one another. Reproductive organs external.

Sub-class I. HYDROIDA (Hydroid Zoophytes).

Order 1. *Hydrida.—Ex.* Fresh-water Polype (Hydra).

Order 2. *Corynida.—Ex.* Pipe-coralline (Tubularia).

Order 3. *Sertularida.—Ex.* Sea-firs (Sertularia).

Sub-class II. SIPHONOPHORA (Oceanic Hydrozoa).

Order 4. *Calycophoridæ.—Ex.* Diphyes.

Order 5. *Physophoridæ.—Ex.* Portuguese Man-of-War (Physalia).

Sub-class III. DISCOPHORA (Jelly-fish).

Order 6. *Medusidæ—Ex.* Trachynema.

Sub-class IV. LUCERNARIDA (Sea-blubbers).

Order 7. *Lucernaridæ.—Ex.* Lucernaria.

Order 8. *Pelagidæ.—Ex.* Pelagia.

Order 9. *Rhizostomidæ.—Ex.* Rhizostoma.

Sub-class V. GRAPTOLITIDÆ (extinct).

CLASS B. ACTINOZOA.—Stomach opening below into the body-cavity, which is divided into a number of compartments by a series of vertical partitions or "mesenteries." Reproductive organs internal.

Order 1. *Zoantharia.*—Tentacles simply rounded, in multiples of five or six.—*Ex.* Sea-Anemones (Actinidæ), Star-corals (Astræidæ), Brain-corals (Meandrina), Madrepores (Madreporidæ).

Order 2. *Alcyonaria.*—Tentacles fringed, in multiples of four.—*Ex.* Dead-man's-toes (Alcyonium), Organ-pipe Coral (Tubipora), Sea-rods (Virgularia), Sea-pens (Pennatula), Red Coral (Corallium).

Order 3. *Rugosa* (extinct).

Order 4. *Ctenophora.*—Animal oceanic, swimming by means of bands of cilia or "ctenophores."—*Ex.* Pleurobrachia, Venus's Girdle (Cestum).

SUB-KINGDOM III.—ANNULOIDA.

Animals in which the alimentary canal is completely shut off from the general cavity of the body, and in which there is a distinct nervous system. A true blood-circulatory system may or may not be present. In all there is a peculiar system of canals, which usually communicate with the exterior, and which constitute what is called the "water-vascular system." The body of the adult is never composed of a succession of definite rings, or provided with successive pairs of appendages disposed symmetrically on the two sides of the body.

The Annuloida are divided into two great classes:

A. ECHINODERMATA.—Integument composed of numerous calcareous plates joined together, or leathery and having grains, spines, or tubercles of calcareous matter developed in it. Water-vascular system (ambulacral system) mostly employed in locomotion, and generally communicating with the exterior. Adult generally more or less starlike or "radiate" in shape; young mostly showing more or less complete "bilateral symmetry," that is, showing similar parts on the two sides of the body. Nervous system radiate.

Order 1. *Crinoidea* (Sea-lilies).—*Ex.* Feather-star (Comatula), Medusa-head Crinoid (Pentacrinus), Stone-lily (Encrinus.)

Order 2. *Blastoidea* (extinct).

Order 3. *Cystoidea* (extinct).

Order 4. *Ophiuroidea* (Brittle-stars).—*Ex.* Sand-stars (Ophiura), Brittle-stars (Ophiocoma).
Order 5. *Asteroidea* (Star-fishes).—*Ex.* Cross-fish (Uraster), Sun-star (Solaster), Cushion-star (Goniaster).
Order 6. *Echinoidea* (Sea-urchins).—*Ex.* Sea-eggs (Echinus), Heart-urchins (Spatangus).
Order 7. *Holothuroidea* (Sea-cucumbers).—*Ex.* Trepangs (Holothuria).

B. SCOLECIDA.—Body usually flattened, or cylindrical and worm-like; integument soft, without lime. Water-vascular system not assisting in locomotion. Nervous system consisting of one or two ganglia or little masses, and not disposed in a radiate manner.

Order 1. *Tæniada.*—*Ex.* Tape-worm (Tænia).
Order 2. *Trematoda* (Suctorial worms).—*Ex.* Liver-fluke (Distoma).
Order 3. *Turbellaria.*—*Ex.* Planarians (Planaria), Ribbon-worms (Nemertes).
Order 4. *Acanthocephala* (Thorn-headed worms).—*Ex.* Echinorhynchus.
Order 5. *Gordiacea* (Hair-worms).—*Ex.* Gordius.
Order 6. *Nematoda* (Thread-worms).—*Ex.* Round-worm (Ascaris), Guinea-worm (Filaria), Vinegar-eel (Anguillula).
Order 7. *Rotifera* (Wheel-animalcules).—*Ex.* Builder-animalcule (Melicerta), Flexible Creeper (Notommata).

SUB-KINGDOM IV.—ANNULOSA.

Animal composed of numerous definite segments or "somites," arranged longitudinally, one behind the other. Nervous system always present, consisting typically of a double chain of nervous masses, or ganglia, which are placed along the lower surface of the body, and form a collar around the gullet. Limbs (when present) turned toward that side of the body on which the main masses of the nervous system are situated.

DIVISION A. ANARTHROPODA.—Locomotive appendages, when present, not distinctly jointed or articulated to the body.

CLASS I. GEPHYREA.—*Ex.* Spoon-worms (Sipunculus).

CLASS II. ANNELIDA (Ringed-worms).

Order 1. *Hirudinea.*—*Ex.* Leeches (Sanguisuga, Hirudo).
Order 2. *Oligochæta.*—*Ex.* Earth-worms (Lumbricus), Water-worms (Nais).
Order 3. *Tubicola.*—*Ex.* Tube-worms (Serpula).
Order 4. *Errantia.*—*Ex.* Sand-worms and Sea-centipedes (Nereis), Lob-worm (Arenicola), Sea-mouse (Aphrodite).

CLASS III. CHÆTOGNATHA (Arrow-worms).—*Ex.* Sagitta.

DIVISION B. ARTHROPODA.—Locomotive appendages jointed or articulated to the body.

CLASS I. CRUSTACEA.—Respiration aquatic, mostly by gills. Two pairs of antennæ. Limbs more than four pairs in number, carried upon the thorax, and generally the abdomen also.

Order 1. *Ichthyophthira.*—*Ex.* Lernæa.
Order 2. *Rhizocephala.*—*Ex.* Peltogaster.
Order 3. *Cirripedia.*—*Ex.* Barnacles (Lepas), Acorn-shells (Balanus).
Order 4. *Ostracoda.*—*Ex.* Water-fleas (Cypris).
Order 5. *Copepoda.*—*Ex.* Cyclops.
Order 6. *Cladocera.*—*Ex.* Branched-horned Water-fleas (Daphnia).

Order 7. *Phyllopoda.—Ex.* Brine-shrimp (Artemia).
Order 8. *Trilobita* (Extinct).
Order 9. *Merostomata.—Ex.* King-crabs (Limulus).
Order 10. *Læmodipoda.—Ex.* Whale-louse (Cyamus).
Order 11. *Isopoda.—Ex.* Wood-lice (Oniscus), Slaters (Ligia).
Order 12. *Amphipoda.—Ex.* Sandhopper (Talitrus), Fresh-water Shrimp (Gammarus).
Order 13. *Stomapoda.—Ex.* Locust-shrimp (Squilla).
Order 14. *Decapoda.—Ex.* Lobster (Homarus), Cray-fish (Astacus), Shrimps (Crangon); Hermit-crabs (Pagurus); Crabs (Cancer, Carcinus), Land-crabs (Gecarcinus).

CLASS II. ARACHNIDA.—Respiration aerial, by pulmonary chambers or air-tubes (tracheæ) in the higher forms. Antennæ converted into jaws. Head and thorax amalgamated. Four pairs of legs. Abdomen without limbs.

Order 1. *Podosomata* (Sea-spiders).—*Ex.* Pycnogonum.
Order 2. *Monomerosomata.—Ex.* Mites (Acarus), Water-mites (Hydrachna), Ticks (Ixodes).
Order 3. *Adelarthrosomata.—Ex.* Harvest-spiders (Phalangidæ), Book-scorpions (Chelifer).
Order 4. *Pedipalpi.—Ex.* Scorpions (Scorpio).
Order 5. *Araneida.—Ex.* House-spiders (Tegenaria), Field-spiders (Epeira).

CLASS III. MYRIAPODA.—Respiration aerial, by tracheæ (air-tubes) or by the skin. Head distinct; remainder of body composed of nearly similar segments. Legs more than eight pairs in number, and borne partly upon the abdomen. One pair of antennæ.

Order 1. *Chilopoda.—Ex.* Centipedes (Scolopendra).
Order 2. *Chilognatha.—Ex.* Millipedes (Iulus).
Order 3. *Pauropoda.—Ex.* Pauropus.

CLASS IV. INSECTA.—Respiration aerial, by tracheæ. Head, thorax, and abdomen distinct. One pair of antennæ. Three pairs of legs, and generally two pairs of wings on the thorax. No locomotive limbs on the abdomen.

Order 1. *Anoplura.—Ex.* Lice (Pediculus).
Order 2. *Mallophaga* (Bird-lice).
Order 3. *Thysanura* (Springtails).
Order 4. *Hemiptera.—Ex.* Plant-lice (Aphides), Field-bug (Pentatoma), Cochineal Insects (Coccus).
Order 5. *Orthoptera.—Ex.* Locusts (Acrydium), Grass-hoppers (Gryllus), Crickets (Achetina), Cockroach (Blatta).
Order 6. *Neuroptera.—Ex.* White Ants (Termes), Dragon-flies (Libellulidæ), May-flies (Ephemeridæ).
Order 7. *Aphaniptera.—Ex.* Fleas (Pulex).
Order 8. *Diptera.—Ex.* Gnats (Culex), Crane-flies (Tipula), House-flies and Flesh-flies (Musca).
Order 9. *Lepidoptera* (Butterflies and Moths).
Order 10. *Hymenoptera.—Ex.* Bees (Apidæ), Humble-bees (Bombidæ), Wasps (Vespidæ), Ants (Formicidæ), Saw-flies, (Tenthredinidæ).
Order 11. *Strepsiptera.—Ex.* Stylops.
Order 12. *Coleoptera* (Beetles).

SUB-KINGDOM V.—MOLLUSCA.

Animal soft-bodied, generally with a hard covering or shell. Nervous

system consisting of a single ganglion or of scattered pairs of ganglia. A distinct heart and breathing-organ, or neither.

The Mollusca may be divided into the two following primary divisions, containing the following classes :—

A. MOLLUSCOIDA.—Nervous system consisting of a single ganglion or of a principal pair of ganglia. No heart, or an imperfect one.

CLASS I. POLYZOA.—Animal always forming compound growths or colonies. No heart. The mouth of each zoöid surrounded by a circle or crescent of ciliated tentacles.—*Ex.* Sea-mats (Flustra), Lace-coral (Fenestella).

CLASS II. TUNICATA.—Animal simple or compound, enclosed in a leathery or gristly case. An imperfect heart.—*Ex.* Sea-squirts (Ascidia).

CLASS III. BRACHIOPODA.—Animal always simple ; the body enclosed in a bivalve shell. Mouth furnished with two long fringed processes or "arms."—*Ex.* Lamp-shells (Terebratula).

B. MOLLUSCA PROPER.—Nervous system consisting of three principal pairs of ganglia. Heart well developed, consisting of at least two chambers.

CLASS IV. LAMELLIBRANCHIATA (Bivalve Shell-fish).—No distinct head ; no teeth. Body enclosed in a shell which is "bivalve," or composed of two distinct pieces. One or two leaf-like gills on each side of the body.—*Ex.* Oyster (Ostrea), Scallop (Pecten), Mussel (Mytilus).

CLASS V. GASTEROPODA.—A distinct head and toothed tongue. Shell absent in some, but mostly present, and usually consisting of a single piece ("univalve"). Locomotion effected by creeping about on the flattened under surface of the body ("foot"), or by swimming by means of a fin-like modification of the same.—*Ex.* Whelks (Buccinum), Limpets (Patella), Sea-lemons (Doris), Land-snails (Helix), Slugs (Limax).

CLASS VI. PTEROPODA.—Animal oceanic, swimming by means of two wing-like appendages, one on each side of the head. Size minute.—*Ex.* Cleodora.

CLASS VII. CEPHALOPODA.—Animal with eight or more arms, placed in a circle round the mouth. Mouth armed with jaws, and and a toothed tongue. Two or four plume-like gills. In front of the body, a muscular tube ("funnel") through which is expelled the water which has been used in respiration. An external shell in some, an internal skeleton in others.—*Ex.* Calamaries (Loligo), Cuttle-fishes or Poulpes (Octopus), Paper-Nautilus (Argonauta), Pearly Nautilus (Nautilus).

VERTEBRATE ANIMALS.

SUB-KINGDOM VI.—VERTEBRATA.

Body composed of a number of definite segments arranged longitudinally, or one behind the other. The main masses of the nervous system are placed on the dorsal aspect of the body, and are completely shut off from the general body-cavity. The limbs (when present) are turned away from that side of the body on which the main nervous masses are situated, and are never more than four in number. In most cases a backbone, or "vertebral column," is present in the fully-grown animal.

CLASS I. PISCES (Fishes).—Breathing-organs in the form of gills. Heart usually of two chambers, rarely of three. Blood cold. Limbs, when present, converted into fins.

Order 1. *Pharyngobranchii.*—*Ex.* Lancelet (Amphioxus).

Order 2. *Marsipobranchii.*—*Ex.* Lamprey (*Petromyzon*), Hag-fish (*Myxine*).

Order 3. *Teleostei* (Bony Fishes). —*Ex.* Eels (Murænidæ), Herrings (Clupeidæ), Salmon and Trout (Salmonidæ), Cod and Haddock (Gadidæ), Flat-fishes (Pleuronectidæ), Perch (Percidæ), Mackerel (Scomberidæ).

Order 4. *Ganoidei.* —*Ex.* Bony Pike (Lepidosteus), Paddle-fish (Spatularia), Sturgeon (Sturio).

Order 5. *Elasmobranchii.*—*Ex.* Sharks (Carcharidæ), Dog-fishes (Scylliadæ), Saw-fishes (Pristis), Rays and Skates (Raiidæ).

Order 6. *Dipnoi.*—*Ex.* Mud-fish (Lepidosiren).

CLASS II. AMPHIBIA (Amphibians).—Breathing-organs in the young in the form of gills alone, afterwards lungs, either alone or associated with gills. Skull joined to the backbone by two articulating surfaces ("condyles"). Limbs never converted into fins. Heart in the young of two chambers only, in the adult of three chambers. Blood cold.

Order 1. *Labyrinthodontia* (extinct).

Order 2. *Ophiomorpha.*—*Ex.* Cæcilia.

Order 3. *Urodela* (Tailed Amphibians). —*Ex.* Water-newts (Triton), Salamanders (Salamandra), Axolotl (Siredon), Mud-eel (Siren).

Order 4. *Anoura* (Tailless Amphibians). —*Ex.* Frogs (Rana), Tree-frogs (Hyla), Toads (Bufo), Surinam Toads (Pipa.)

CLASS III. REPTILIA (Reptiles).—Respiratory organs in the form of lungs, never in the form of gills. Heart three-chambered, rarely four-chambered, the pulmonary and systemic circulations always connected together directly, either in the heart itself or in its immediate neighbourhood. Blood cold. Skull jointed to the backbone by a single articulating surface or "condyle." Each half of the lower jaw composed of several pieces. Appendages of the skin in the form of scales or plates.

Order 1. *Chelonia.* —*Ex.* Turtles (Cheloniidæ), Soft Tortoises (Trionycidæ), Terrapins (Emydidæ), Land Tortoises (Testudinidæ).

Order 2. *Ophidia.*—*Ex.* Vipers (Viperidæ), Rattlesnakes (Crotalidæ), Sea-snakes (Hydrophidæ), Boas and Pythons (Boidæ).

Order 3. *Lacertilia.*—*Ex.* Lizards (Lacerta), Iguanas (Iguanidæ), Monitors (Varanidæ), Chameleons (Chamæleontidæ).

Order 4. *Crocodilia.*—*Ex.* Crocodiles, Alligators, Gavials.

Order 5. *Ichthyopterygia* (extinct).—*Ex.* Ichthyosaurus.

Order 6. *Sauropterygia* (extinct).—*Ex.* Plesiosaurus.

Order 7. *Pterosauria* (extinct).—*Ex.* Pterodactylus.

Order 8. *Anomodontia* (extinct).—*Ex.* Dicynodon.

Order 9. *Deinosauria* (extinct).—*Ex.* Iguanodon.

CLASS IV. AVES (Birds).—Respiratory organs in the form of lungs, never in the form of gills. Lungs connected with air-receptacles placed in different parts of the body. Heart four-chambered. Blood warm. Skull connected with the backbone by a single articulating surface or "condyle." Each half of the lower jaw composed of several pieces. Appendages of the skin in the form of feathers. Cavities of the chest and abdomen not

separated by a complete partition (diaphragm). Fore-limbs converted into wings. Animal oviparous.

Order 1. *Natatores* (Swimmers). — *Ex.* Penguins (Spheniscidæ), Gulls (Laridæ), Ducks (Anatidæ), Geese (Anserinæ), Flamingos (Phænicopteridæ).

Order 2. *Grallatores* (Waders).—*Ex.* Rails (Rallidæ), Water-hens (Gallinulæ), Cranes (Gruidæ), Herons (Ardeidæ), Storks (Ciconinæ), Snipes and Woodcock (Scolopacidæ), Plovers, Oyster-catchers, and Turnstones (Charadriidæ).

Order 3. *Cursores* (Runners).—*Ex.* Ostrich (Struthio), American Ostrich (Rhea), Emeu (Dromaius), Cassowary (Casuarius), Apteryx.

Order 4. *Rasores* (Scratchers). — *Ex.* Grouse, Ptarmigan, Partridges, Pheasants, Turkey, Guinea-fowl, Domestic Fowl, Pea-fowl (Gallinacei); Doves, Pigeons, Ground-pigeons (Columbacei).

Order 5. *Scansores* (Climbers).—*Ex.* Cuckoos (Cuculidæ), Woodpeckers (Picidæ), Parrots, Cockatoos, Parrakeets (Psittacidæ), Toucans (Rhamphastidæ), Trogons (Trogonidæ).

Order 6. *Insessores* (Perchers).—*Ex.* Crows, Magpies, and Jays (Corvidæ), Starlings (Sturnidæ), Finches, Grosbeaks, Larks (Fringillidæ), Thrushes, Blackbirds, Orioles (Merulidæ), Creepers and Wrens (Certhidæ), Humming-birds (Trochilidæ), Swallows and Martins (Hirundinidæ), Swifts (Cypselidæ), King-fishers (Alcedinidæ).

Order 7. *Raptores* (Birds of Prey).—*Ex.* Owls (Strigidæ), Falcons and Hawks (Falconidæ), Eagles (Aquilina), Vultures (Vulturidæ).

Order 8. *Saururæ* (extinct).—*Ex.* Archæopteryx.

CLASS V. MAMMALIA (Mammals or Quadrupeds).—Respiratory organs in the form of lungs, which are never connected with air-sacs placed in different parts of the body. Heart four-chambered. Blood warm. Skull united to the backbone by two articulating surfaces or "condyles." Each half of the lower jaw composed of a single piece. Appendages of the skin in the form of hairs. Young nourished by means of a special fluid—the milk,—secreted by special glands—the mammary glands. Animal viviparous.

A. NON-PLACENTAL MAMMALS.—The young not provided with a placenta.

Order 1. *Monotremata.*—*Ex.* Duck-mole (Ornithorhynchus), Spiny Ant-eater (Echidna).

Order 2. *Marsupialia.* — *Ex.* Kangaroos (Macropodidæ), Kangaroo-bear (Phascolarctos), Phalangers (Phalangistida), Opossums (Didelphidæ), Tasmanian Devil (Dasyurus).

B. PLACENTAL MAMMALS.—The young provided with a placenta.

Order 3. *Edentata.*—*Ex.* Sloths (Bradypodidæ), Armadillos (Dasypodidæ), Hairy Ant-eaters (Myrmecophagidæ), Scaly Ant-eaters (Manis).

Order 4. *Sirenia.*—*Ex.* Manatee (Manatus), Dugong (Halicore).

Order 5. *Cetacea.* — *Ex.* Whalebone-whales (Balænidæ), Sperm-whales (Physeteridæ), Dolphins and Porpoises (Delphinidæ).

Order 6. *Ungulata* (Hoofed Quadrupeds).—*Ex.* Rhinoceros; Tapir; Horse, Ass, and Zebra (Equidæ); Hippopotamus; Hogs and Peccaries (Suida); Camels and Llamas (Camelidæ); Giraffe; Stags, Elk, Reindeer (Cervidæ); Antelopes (Antilopidæ); Sheep and Goats (Ovidæ); Oxen and Buffaloes (Bovidæ).

Order 7. *Hyracoidea.*—*Ex.* Hyrax.

Order 8. *Proboscidea.*—*Ex.* Elephants (Elephas).

Order 9. *Carnivora.*—*Ex.* Seals (Phocidæ), Bears (Ursidæ), Racoons (Procyon), Badgers (Melidæ), Weasels and Otters (Mustelidæ), Civets and Genettes (Viverridæ), Dogs, Wolves, and Foxes (Canidæ); Hyænas (Hyænidæ), Cats, Lynxes, Leopards, Tigers, Lions (Felidæ).

Order 10. *Rodentia.*—*Ex.* Hares and Rabbits (Leporidæ), Porcupines (Hystricidæ), Beavers (Castoridæ), Mice and Rats (Muridæ), Dormice (Myoxidæ), Squirrels and Marmots (Sciuridæ).

Order 11. *Cheiroptera.*—*Ex.* Common Bats (Vespertilionidæ), Horseshoe-bats (Rhinolophidæ), Vampire-bats (Phyllostomidæ), Fox-bats (Pteropidæ).

Order 12. *Insectivora.*—*Ex.* Moles (Talpidæ), Shrew-mice (Soricidæ), Hedgehogs (Erinaceidæ).

Order 13. *Quadrumana.*—*Ex.* Aye-aye (Cheiromys), Lemurs (Lemuridæ), Spider-monkeys (Ateles), Howlers (Mycetes), Macaques (Macacus), Baboons (Cynocephalus), Gibbons (Hylobates), Orang (Simia), Gorilla and Chimpanzee (Troglodytes).

Order 14. *Bimana.*—Man (Homo Sapiens).

General Succession and Progression of Organic Types.—Whilst admitting the impossibility of arranging the animal kingdom upon any linear plan, no doubt obtains as to the fact that some of the fundamental "morphological types," or plans upon which animals have been constructed, are higher than others. Every one admits, for example, that the Vertebrate type is higher than the Molluscan or the Articulate type, an admission which is not affected by the fact that the highest Molluscs and Articulates are superior in point of organisation to the lowest Vertebrates. In the same way, within the limits of each sub-kingdom, every one admits that some of the groups are higher than the others. Every one, for example, would admit that a Mammal is a superior animal to a Fish. It follows from this that a certain general arrangement of the animal kingdom, as a whole, is possible, upon the comparative basis of the morphological type of the sub-kingdoms. Similarly a general and more exact arrangement of the classes and orders of each sub-kingdom may be made by the degree of perfection in which the type of the sub-kingdom is carried out in each.

No generalisation of Palæontology seems to stand on a

firmer basis than that which asserts that there has been a general succession of organic types, and that the appearance of the lower forms of life has in the main preceded that of the higher forms in point of time. In other words, it is one of the generalisations of Palæontology that there has not only been a *succession*, but also a *progression*, of organic types in proceeding from the earliest fossiliferous deposits up to the present day. Whilst this *general* law remains, as we believe, unassailable, there are some important considerations which must not be lost sight of. In the first place, it is very doubtful if we are as yet acquainted with the *absolute* time of the first appearance upon the globe of even one of the sub-kingdoms. Future discoveries, therefore, are almost certain to push back still further into the remote vistas of the past the point of time at which each morphological type first made its appearance upon the globe. Still, there is little likelihood that the *relative* times of appearance of the great groups, as compared with one another, will be affected by the researches of the future. It remains almost certain that we shall find that the lower types were followed in point of time by the higher.

In the second place, we find all the primary types in existence before the close of the Silurian period; and he would be rash indeed who would dogmatically deny that they might all have been present in the earlier Cambrian period. This, at first sight, might seem almost to negative the above generalisation, but it does not affect its value if fairly examined. The lower sub-kingdoms of the Invertebrate animals appeared so early that their origin is lost in the mists of antiquity, and we can say nothing positively as to the time when each came into existence. The Cambrian deposits are underlaid by the vast series of the Laurentian deposits, representing an incalculable lapse of time. These ancient sediments, with one exception, have hitherto proved barren of life, owing to the intense metamorphism to which they have been subjected, and they consequently yield no evidence bearing on the question in hand. They serve to show us, however, by their presence alone, that we must in the meanwhile leave the Invertebrate sub-kingdoms out of account altogether as bearing upon the question of the succession and progression of organic types. We do not know when these sub-kingdoms commenced, and hence we have no right to assert either that they were all introduced simultaneously, or that they came into being successively. We may be sure, however, of one thing—they did not commence at the points where now we find their earliest traces. There remains, then, only the sub-kingdom of the Vertebrate animals which can

reasonably be appealed to as evidence on this question. The stratified series is long enough to render it certain that it contains traces of the first appearance of, at any rate, the higher classes of these, though we doubtless are ignorant of the absolute moment at which each appeared. If, therefore, it can be shown that there has been a progression as far as this sub-kingdom is concerned, then there would, by analogy, be the greatest probability that a similar progression has taken place in all the sub-kingdoms.

So far as our present knowledge goes, it would appear that there *is* such a progression in the Vertebrate sub-kingdom. The classes of Vertebrates make their appearance, on the whole, in the order indicated by their zoological position, the lowest first and the highest last. Not only does this hold good for the classes of the Vertebrates, but the same *general* statement may be made as to the orders of each class. Where apparent exceptions occur, a reasonable explanation can be given, or our knowledge can be shown to be defective. Space will not allow a discussion of this question, but a single example may be taken. So far as we know at present, the earliest remains of vertebrate animals are those of Fishes—the lowest class of the sub-kingdom—and these appear in the Upper Silurian Rocks for the first time. Granting the probability that Fishes may some day be found in the Lower Silurian Rocks, or even in Cambrian deposits, there still seems no likelihood that they will be deprived by any future discoveries of their position as being the earliest of their sub-kingdom. The oldest remains of Fishes, however, are by no means those which would be expected, but belong to two of the higher orders of the class. This seeming anomaly, however, disappears when we consider that the two lowest orders of Fishes possess no structures by which we can reasonably expect to find them recorded in a fossil state. They may therefore have been in existence long before the Ganoids and Placoids of the Upper Silurian Rocks, and we have no right to assume that they were not. As to the remaining great order of Fishes (the Teleostean Fishes), it is certain that their appearance was much later, and they are generally regarded as inferior to the Ganoids and Placoids in zoological position. This, however, is a matter of opinion, and reasons are not wanting for regarding them as the highest of their class.

It only remains to add that nothing further is contended for here than the general fact of there having been a progression of morphological types, the lowest presenting themselves first, the highest being the last to appear upon the scene. It is by no

means contended that the Ganoid fishes of the Upper Silurian Rocks were in any way degraded members of their order, or inferior in point of organisation to the Ganoids of the present day. On the contrary, there is reason to think that many types early presented a development more varied than that exhibited by their successors. It is simply contended that, *on the whole*, there has been a zoological progression as we ascend from the Cambrian period to the present day. It is also to be remembered, that though the commencement of the Invertebrate sub-kingdoms may be unknown to us, a similar progression can be in many cases shown as regards the *orders* and *classes* of these, even more completely than in the case of the Vertebrate sub-kingdom.

PART II.

PART II.

CHAPTER VII.

SUB-KINGDOM I.—PROTOZOA.

SUB-KINGDOM I. PROTOZOA. — *Animal simple or composite, generally of very minute size, composed of a structureless, jelly-like, albuminoid substance (termed "sarcode"), showing no composition out of definite parts or segments, having no definite body-cavity, presenting no traces of a nervous system, and having either no alimentary apparatus, or but a very rudimentary one.*

TABLE OF THE DIVISIONS OF THE PROTOZOA.

CLASS A. GREGARINIDÆ.—Parasitic Protozoa, which are destitute of a mouth, and do not possess the power of emitting processes of their body-substance (pseudopodia).

CLASS B. RHIZOPODA.—Protozoa, which are destitute of a mouth, and have the power of emitting extensile and contractile processes of the body-substance (pseudopodia).

Order 1. *Monera.—Ex.* Protogenes.
Order 2. *Amœbea.—Ex.* Amœba.
Order 3. *Foraminifera.—Ex.* Nummulites.
Order 4. *Radiolaria.—Ex.* Haliomma.
Order 5. *Spongida.—Ex.* Spongilla.

CLASS C. INFUSORIA (Infusorian Animalcules).—Protozoa mostly with a mouth, and rudimentary digestive canal; destitute of the power of emitting pseudopodia; furnished with vibratile cilia or contractile filaments; the body usually with a distinct cuticle covering a layer of firm sarcode.

Regarded palæontologically, we may eliminate from the *Protozoa* the entire class of the *Gregarinidæ*, with the Rhizopodous orders of the *Monera* and *Amœbea*, no trace of the past existence of which has yet been obtained, or, from their soft-bodied nature, is ever likely to be. For all practical purposes the same may be said of the large and universally-distributed class of the Infusorian Animalcules. Some of these, however, possess horny or membranous cases which might possibly be preserved in a fossil state; and it has been alleged that the genus *Peri-*

dinium has been thus detected in the Cretaceous formation. With this doubtful exception, however, no Infusorian animalcule has ever been detected in the fossil state, though the class has doubtless existed from the most remote antiquity. There remain, then, only the three Rhizopodous orders of the *Foraminifera*, *Radiolaria*, and *Spongida*, all of which secrete hard structures, and all of which are more or less extensively represented as fossils, so that they demand our attention separately and in detail.

I.—Foraminifera.

The *Foraminifera* may be defined as *Rhizopoda in which the body is protected by a shell or "test," which is usually composed of carbonate of lime, but which may consist of particles of sand cemented together by some animal cement, or may be simply horny (chitinous). The animal may be simple, or may repeat itself indefinitely by budding, and the body-substance gives out long and thread-like processes (pseudopodia), which interlace with one another to form a network, and often coalesce at their bases to form a continuous layer of sarcode outside the shell. The pseudopodia reach the exterior either by perforations in the walls of the shell, or simply by the mouth of the latter* (fig. 6, *c b*).

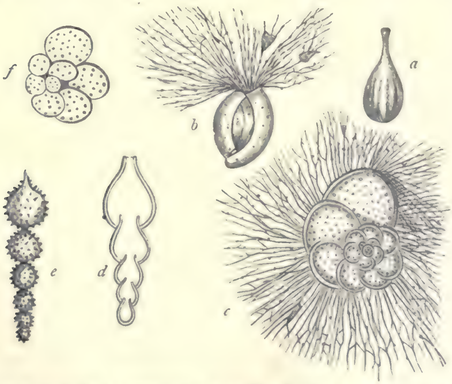


Fig. 6.—Morphology of Foraminifera. *a Lagena vulgaris*, a monothalamous Foraminifer; *b Miliola* (after Schultze), showing the pseudopodia protruded from the oral aperture of the shell; *c Discorbina* (after Schultze), showing the nautiloid shell with the foramina in the shell-wall giving exit to pseudopodia; *d* Section of *Nodosaria* (after Carpenter); *e Nodosaria hispida*; *f Globigerina bulloides*.

From a palæontological point of view the only part of a Foraminifer with which we have to deal is the shell or "test," and there are several points to notice in this connection. Firstly, as regards the actual composition of the shell, it is in the majority of cases calcareous, or composed of carbonate of lime, but it is rarely membranous, and it is not uncommonly "arenaceous"—that is, composed of particles of sand cemented together by some animal substance. Secondly, the shells of the *Foraminifera* may be divided into two natural groups, according as their walls are, or are not, perforated by apertures or "foramina" through which the pseudopodia are protruded. In those calcareous shells in which the walls are not perforated the substance of the test is "porcellanous," homogeneous, and opaque-white when viewed by reflected light. In those calcareous shells in which the walls are perforated by pseudopodial foramina, the substance of the test is "vitreous," transparent, and glassy. The arenaceous shells may or may not be perforated, their texture in either case remaining the same. Thirdly, there are some convenient, though arbitrary, distinctions to be drawn from the *form* of the shell. The simplest form amongst the *Foraminifera*, and that in which all alike primitively commence their existence, is that of a single spheroid of sarcode capable of secreting for itself a hard covering, as in *Lagena* (fig. 6, *a*) and *Orbulina* (fig. 7). This simple state of things is rarely retained throughout life, but the primitive mass of sarcode usually repeats itself by budding, till a compound mass is produced, consisting of a number of little spheres of sarcode, surrounded by a common calcareous or arenaceous envelope or test. Each bud of the compound *Foraminifer* is surrounded by its own shell, so that the whole comes to be composed of a number of chambers, each containing a mass of sarcode. The partitions, however, or "septa," between the different chambers, are perforated by one or more apertures (fig. 6, *d*), through which pass connecting bands of sarcode; so that the sarcode occupying the different chambers is united into a continuous and organic whole. Each member of the colony may give out its own pseudopodia through perforations in its investing wall (fig. 6, *c*), or the pseudopodia may be simply emitted from the mouth of the shell by the last segment only (fig. 6, *b*). In any case the direction in which the buds are thrown out by the primordial spherule of sarcode is governed by a determinate law, and differs in different species, the form ultimately assumed

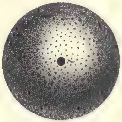


Fig. 7.—*Orbulina universa.* A simple Foraminifer from the Pliocene strata (Sub-Apennine beds) of Italy. D'Orbigny.

by the shell depending wholly upon this. The forms, however, assumed by the shells of *Foraminifera* are extremely variable, even within the limits of a single species, and it would be impossible to notice even the chief types in this place. There are, however, two or three important variations which may be noticed. If the buds are thrown out from the primitive spherule in a linear series so as to form a shell composed of numerous chambers arranged in a straight line, we get such a type as *Nodosaria* (fig. 6, *e*). When the new chambers are added in a spiral direction, each being a little larger than the one which preceded it, and the coils of the spiral lying in the same plane, we get such a form as *Discorbina* (fig. 6, *c*), or *Robulina* (fig. 8). These are the so-called "nautiloid" *Foraminifera*, from the resemblance of the shell in figure to that of the Pearly Nautilus. From this resemblance the nautiloid *Foraminifera* were originally placed in the same class as the *Ammonites* (*Cephalopoda*), but their true position was shown by the examination of their soft parts. In the typical nautiloid shell the convolutions of the spiral all lie in one plane; but in other cases, as in *Rotalia* (fig. 9) the shell becomes turreted or top-shaped, in consequence of the coils of the spiral passing obliquely round a central axis. In other forms, such as *Nummulites* (fig. 13), *Orbitolites*, and *Orbitoides*, the shell, though consisting essentially of a succession of chambers arranged in a spiral series, is of a much more complex nature. Lastly, in addition to these symmetrical forms, there are others, such as *Globigerina* (fig. 6, *f*), in which the arrangement of the segments is very irregular.

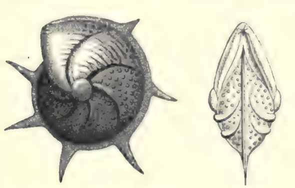


Fig. 8.—*Robulina echinata*, a "nautiloid" Foraminifer. D'Orbigny.

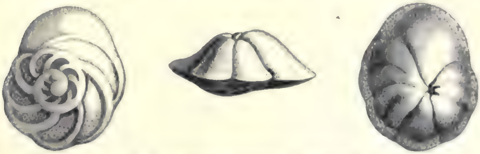


Fig. 9.—*Rotalia Boueana*. D'Orbigny.

Remains of *Foraminifera* have been found in all the great

formations into which the stratified series is divided, from the Laurentian period to the present day. In one of the limestones of the vast Laurentian series of Canada occurs a singular body which has been described as a gigantic *Foraminifer*, under the name of *Eozoön Canadense* (fig. 10). Some observers doubt the true organic nature of *Eozoön*, but the weight of authority is decidedly in favour of the belief that the above is its real character. If this be the case, *Eozoön* is not only the oldest of the *Foraminifera*, but is the earliest fossil of any kind as yet discovered. *Eozoön* consists of a chambered calcareous skele-

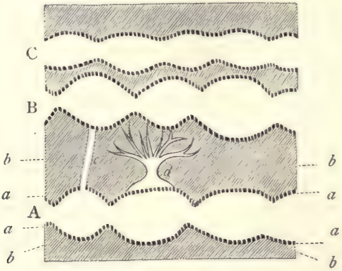


Fig. 10.—Diagram of a portion of *Eozoön* (after Carpenter).—A, B, C, Three tiers of chambers communicating with one another by constricted apertures; *a a* The true shell-wall, perforated by numerous pseudopodial foramina; *b b* Intermediate skeleton; *c* Passage of communication (stolon-passage) from tier to tier; *d* Ramifying tubes in the intermediate skeleton.

ton infiltrated by certain silicates in solution. These silicates are chiefly white pyroxene, serpentine, and Loganite, and they are now found occupying all the spaces in the fossil which were formerly filled with the sarcode of the animal. When, therefore, a specimen of *Eozoön* is treated with acid, the calcareous matter is dissolved out, and what we have left consists of a cast in the above silicates of the chambers formerly occupied by the sarcode of the animal, together with the various passages by which these chambers are connected, and the tubes by which the pseudopodia were conducted to the exterior. That such a replacement of an animal body by silicated minerals is not an impossibility is shown by the occurrence of casts of living *Foraminifera* (such as *Amphistegina*) in which the sarcode is replaced by a green silicate (probably glauconite), which forms an accurate cast of the interior of the shell. *Eozoön* consists essentially of a series of chambers placed in tiers (fig. 10, A, B, C) which are arranged one above the other.

Sometimes its growth was very regular, but sometimes extremely irregular. The chambers are more or less perfectly marked off from one another by inflections of the test or "septa," perforated for the passage of bands of sarcode, by which the chambers are brought into organic connection. The sarcode occupying the tiers of chambers is bounded by a thin "proper wall" (fig. 10, *a a*), perforated by numerous minute tubes by which the pseudopodia reached the exterior. It is obvious, however, that only the chambers of the uppermost tiers could thus have the power of giving out pseudopodia. The various tiers of chambers are connected with one another by a canal-system, and are separated from one another by the development of supplementary layers of calcareous matter, constituting what is called the "intermediate skeleton." *Eozoön* appears to have grown in reef-like masses, often of very great extent, and it finds its nearest living allies in the recent *Polytrema* and *Carpenteria*. Its shell-structure also shows points of affinity with the extinct *Nummulites* and the recent *Calcarina*. *Eozoön* has been detected, not only in the Laurentian series of Canada, but in other rocks supposed to be of the same age in Bavaria and in other parts of Europe. It also occurs in the Lower Silurian marbles of Connemara in Ireland; and it is said to have been detected in rocks of Liassic age.

Having given a somewhat detailed account of the singular *Eozoön*—justified by its importance—it will not be necessary to speak at any length of the more modern representatives of the order. In the Silurian Rocks remains of *Foraminifera* have been detected in various localities, some of the forms apparently being identical with existing types. Thus, Ehrenberg showed that the Lower Silurian sandstones of the neighbourhood of St Petersburg contained casts of Foraminiferous shells in glauconite, some of which were referable to the living genera *Rotalia* and *Textularia*. Over wide areas in the Southern Alps, Russia, Spain, Armenia, and the United States, beds of Carboniferous limestone are charged with the shells of *Fusulina* (fig. 11). Whole beds are made up of the remains of this minute fossil, and the Fusulina limestone has been justly paralleled with the Nummulitic Limestone of Eocene times.

Fig. 11.—*Fusulina cylindrica*. Carboniferous, Russia.

In the Secondary Rocks, *Foraminifera* occur in great abundance, but they are not specially noticeable except for the part

they play in the formation of Chalk. The great formation of the White Chalk—forming the well-known chalk-cliffs of the south of England, and attaining sometimes a thickness of not less than 1000 feet—is to a very large extent composed of the debris of the microscopic shells of *Foraminifera*. As already pointed out, therefore, the White Chalk is to some extent comparable with the ooze of the deep Atlantic, which is also largely made up of the skeletons of these minute organisms. Amongst the *Foraminifera* of the Chalk are the genera *Globigerina* (fig. 6, *f*), *Rotalia* (fig. 9), and *Textularia* (fig. 12), all of which are represented by living species, no difference being distinguishable in the case of the first between the Cretaceous and the modern form. In the Cretaceous formation (Upper Greensand) we have also the gigantic Arenaceous Foraminifer which constitutes the genus *Parkeria*, the shell of which attains a diameter of two and a quarter inches.

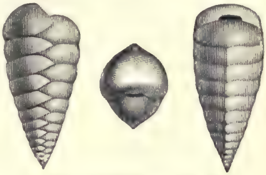
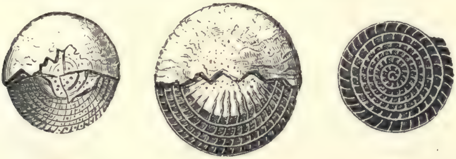


Fig. 12.—*Textularia Meyeriana*. D'Orbigny.

In the Kainozoic period the *Foraminifera* attained their maximum of development, both as regards their size and the number of generic types. The Eocene formation especially is remarkable for the profusion of its Foraminiferous fauna. The Middle Eocene in particular is characterised by the possession of a very widely spread and easily recognised formation, known as the Nummulitic Limestone, from the occurrence in it of a large coin-shaped *Foraminifer*, the *Nummulite* (fig. 13). Nummulites attain a size of as much as three inches in circumference, and their structure is very complex. According to Sir Charles



1 2 3

Fig. 13.—*Nummulites lævigatus*. Eocene.

Lyell, "the Nummulitic Limestone, with its characteristic fossils, plays a far more conspicuous part than any other

Tertiary group in the solid framework of the earth's crust, whether in Europe, Asia, or Africa. It often attains a thickness of many thousand feet, and extends from the Alps to the Carpathians, and is in full force in the north of Africa, as in Algeria or Morocco. It has also been traced from Egypt, where it was largely quarried of old for the building of the Pyramids, into Asia Minor, and across Persia, by Bagdad, to the mouths of the Indus. It occurs not only in Cutch, but in the mountain-ranges which separate Scinde from Persia, and which form the passes leading to Cabul; and it has been followed still further eastwards into India, as far as Eastern Bengal and the frontiers of China." Another important member of the Eocene Rocks is the Miliolite Limestone of the Paris basin, so called because of the abundance in it of the shells of a species of *Miliola*, of which a living form is shown in fig. 6, *b*.

II.—Radiolaria.

The order *Radiolaria* is defined as comprising those members of the *Rhizopoda which possess a siliceous test or siliceous spicules, and are provided with pseudopodia which stand out from the body like radiating filaments, and occasionally run into one another* (fig. 14).

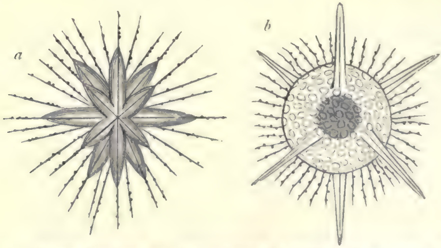


Fig. 14.—Recent Radiolaria. *a Acanthometra*; *b Haliomma*, one of the *Polycystina*, showing the siliceous test and radiating pseudopodia.

All the *Radiolaria* possess hard structures in the form of siliceous spicules or a siliceous test; but only one group, viz., that of the *Polycystina*, has as yet been detected in a fossil condition. The *Polycystina* (fig. 14, *b*) are all microscopic organisms very closely allied to the *Foraminifera*, from which they differ chiefly in the siliceous nature of their skeleton. The test is glassy, composed of flint, perforated by numerous

foramina for the emission of pseudopodia, and often provided with spine-like projections. The *Polycystina* are best known as occurring in the so-called "Infusorial Earth" of Barbadoes. This is a Tertiary deposit, and consists largely of the shells of *Polycystina*. They have not as yet been detected in any Palæozoic formation, but they are known to occur in the Mesozoic series.

III.—Spongida.

The Sponges may be defined as *Rhizopoda composed of numerous amœbiform masses of sarcode united into a composite mass, which is traversed by canals opening on the surface, and is almost always supported by an internal skeleton or framework of horny fibres or of calcareous or siliceous spicula.*

The only portion of the Sponges with which the palæontologist is concerned, is the skeleton. Whatever the nature of this skeleton may be, it is so arranged that its parts surround two sets of apertures which open on the surface of the sponge, and which are connected with one another by a system of canals ramifying in its deeper portions. Of the apertures which penetrate the substance of the sponge in every direction, one set consists of large chimney-like openings, which are called "oscula," or "exhalant apertures." There may be only a single osculum, or many may be present. The other set consists of very much smaller openings, which are always very numerous, and which are termed the "pores," or "inhalant apertures." The pores and oscula are connected by a system of canals excavated in the substance of the sponge, and a constant circulation of water can be kept up through the whole mass, the former serving for the incoming currents, the latter for the outgoing.

The Sponges are divided into three groups according to the nature of the skeleton: 1. *Keratosa*, comprising the ordinary sponges of commerce, in which the skeleton is composed of a horny substance called "keratode;" 2. *Calcarea*, or *Calcispongiæ*, in which the skeleton is composed of carbonate of lime; and 3. *Silicea*, or *Vitrea*, in which the skeleton is composed of flint or silex.

The Horny Sponges, from the nature of their skeleton, are not certainly known as fossils; but traces of their past existence are said to have been obtained in the form of the spicules with which the horny skeleton is sometimes furnished. The Calcareous and Siliceous Sponges are both well represented in a fossil condition, though the true nature of some of the more

ancient examples is perhaps somewhat dubious. As far as we know at present, the *Calcispongiæ* commence in the Silurian Rocks, attain their maximum in the Secondary Rocks, and are diminished in numbers at the present day; though Haeckel's recent discoveries have rendered this last assertion more than problematical. The *Silicispongiæ* seem to have come into existence during the Secondary period, attaining a great development during the Cretaceous epoch, and being well represented at the present day.

As regards Palæozoic sponges, one of the earliest known forms is the *Archæocyathus* (fig. 15) of Mr Billings, species of which have been obtained from the Potsdam Sandstone and Calciferous Sand-rock (Upper Cambrian?) of Canada. The general form in this genus is that of a hollow cone or hollow cylinder, enclosing a large cup-shaped cavity, and tapering towards one extremity, which was presumably fixed to some foreign body. Specimens appear to have reached a very large size, a length of two or three feet and a diameter of three or four inches being sometimes attained. The sponge consists of an outer wall, usually perforated with numerous small irregular apertures, and a thin inner wall pierced with many openings (fig. 15, *a*). The space between the outer and inner wall is subdivided into a number of vertical radiating partitions, thus very closely simulating the structure of one of the septate corals. The genus, however, is shown truly to belong to the *Spongida* by the occurrence of numerous branching, cylindrical, or fusiform siliceous spicula within the substance of the organism. In the same geological horizon, and also in higher strata, occurs the somewhat allied genus *Calathium*, in which the skeleton also assumed a turbinate form.

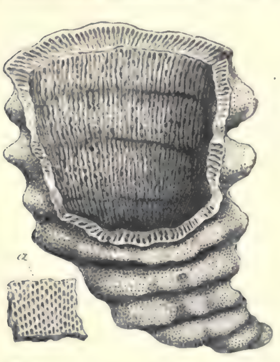


Fig. 15.—Restoration of the lower part of *Archæocyathus Minganensis*; *a* the pores of the inner wall of the cup. (After Billings.)

Amongst the Lower Silurian genera of Sponges may be mentioned *Palæospongia*, *Acanthospongia*, *Eospongia*, *Palæomanon*, and *Astylospongia* (fig. 16). In the last, we have a

globular sponge, provided with a cup-shaped cavity, on which the oscula open, whilst the pores open upon the external surface of the sphere. It was a calcareous sponge, enjoying a free mode of existence, and it presents points of decided affinity to the recent genus *Grantia*. In the Upper Silurian Rocks occur many sponges, one of the most interesting genera being *Amphispongia*, comprising calcareous sponges, oblong or sub-clavate in shape, containing a central cavity, and probably opening above by a single osculum. On this horizon occurs also the genus *Favospongia*; and here, as well as in the Lower Silurians, we have the singular genus *Stromatopora*, which will be spoken of immediately. In the Devonian Rocks, the genus *Sparsispongia* may be noted; but the Carboniferous series has hitherto proved singularly destitute of sponges. In the Permian Rocks it is worthy of notice that there occurs a genus described by Geinitz under the name of *Spongillopsis*, and believed by him to be most nearly allied to the recent fresh-water sponges (*Spongilla*). This is a remarkable fact as bearing upon Professor Ramsay's view, that the Permian Rocks were deposited in inland waters of great extent.

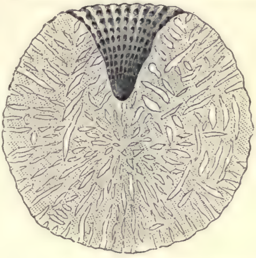


Fig. 16.—Section of *Astylospongia præmorsa*, a lower Silurian Sponge (after Roemer).

Leaving the Palæozoic series, the sponges of the Triassic and Jurassic formations call for no special remark, except that the latter series abounds with examples of the *Calcispongiæ*. It is in the Cretaceous system, however, in which we meet with the greatest development of the sponges. The flints which form such a characteristic feature in the White Chalk are, in some measure at any rate, "connected with the periodic growth of large crops of the sponges" (Owen); and in some sections of flint are found minute "spherical bodies, covered with radiating and multicuspid spines," which have been termed *Spiniferites* or *Xanthidia*, and are probably the "gemmules" of sponges. (By some, however, these are regarded as being the "sporangia" of the *Desmidiæ*, an order of the *Protophyta*.) The two most notable genera of Cretaceous Sponges are *Siphonia* and *Ventriculites*. The *Siphoniæ* (fig. 17) belong to a group of sponges termed *Petrospongiadæ*, from their possession of a stony reticulate skeleton without spicula.

They consist of a pear-shaped mass, supported upon a longer or shorter stem, which breaks up at its base into a number of root-like processes of attachment. At the summit of the pyriform head is a single chimney-like osculum. In many respects

Fig. 17.—*Siphonia ficus*, a Cretaceous Sponge. D'Orbigny.

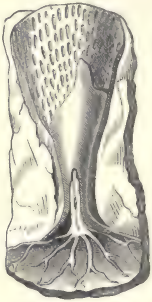


Fig. 18.—*Ventriculites radiatus*. White Chalk. (After Lyell.)

the *Siphoniæ* present a curious resemblance to the *Holteniæ* of the Atlantic ooze, and, like these, they probably were denizens of a deep sea. The genus, however, is not known to occur in strata younger than the Chalk.

Still more closely allied to the living *Holteniæ* are the *Ventriculites* of the Chalk (fig. 18). These "have usually the form of graceful vases, tubes, or funnels, variously ridged or grooved, or otherwise ornamented on the surface, frequently expanded above into a cup-like lip, and continued below into a bundle of fibrous roots. The minute structure of these bodies shows an extremely delicate tracery of fine tubes, sometimes empty, sometimes filled with loose calcareous matter dyed with peroxide of iron" (Wyville Thomson). Like the *Siphoniæ*, the genus *Ventriculites* is not known to occur above the Chalk.

The Tertiary Sponges call for no special comment; but it may be noticed that the great apparent predominance of the

Horny Sponges in our present seas, may be explained by the fact that the members of this group cannot be recognised in a fossil state except by their siliceous spicula, and that these are only sometimes present, and are necessarily very difficult of detection. The genus *Cliona* alone, comprising the singular boring sponges, has managed to survive from the commencement of the Palæozoic period to the present day. Shells mined by species of this genus occur in the Silurian Rocks, and the genus is well represented in recent seas.

Fossils of doubtful Affinities.—Before leaving the *Protozoa*, there are two fossils of doubtful relationships which may be briefly noticed—viz., *Stromatopora* and *Receptaculites*. These show points of affinity to the *Foraminifera* on the one hand, and the Sponges on the other hand, whilst the former approaches the Corals in some respects. Both, however, may, with the greatest probability, be regarded as peculiar types of Sponges.

Stromatopora (fig. 19) forms hemispherical, globular, or irregular masses, often of very considerable size, and sometimes

Fig. 19.—A small and perfect specimen of *Stromatopora rugosa* (Hall). From the Memoirs of the Geological Survey of Canada.

demonstrably attached to shells. In its structure, *Stromatopora* consists of numerous thin, concentric laminæ, penetrated by minute tubes, the mouths of which appear on the surface

of each lamina as minute pores. Species of the genus occur in both Lower and Upper Silurian strata, and in the Devonian series, apparently not completely disappearing till towards the close of the Triassic period.

Receptaculites (fig. 20), in its most perfect condition, is described by Mr Billings as being "of a discoid, cylindrical, ovate, or globular shape, hollow within, and usually, if not always, with an aperture in the upper side. In or near the centre of the lower side there is generally to be seen a small rounded protuberance, indicating, most probably, the position of the primitive cell or nucleus from which the animal commenced its growth. . . . The body-wall is of a somewhat complex structure. It consists of three parts—an external and an internal integument, and, between these, a peculiar tubular or spicular skeleton." The inner and outer integuments are composed of numerous rhomboidal calcareous plates, closely fitting together, and arranged in peculiar curved rows, giving fragments of the fossil very much the appearance of the engine-turned case of a watch. The inner integument differs from the outer in being pierced by numerous small apertures, which open into the central cavity, an aperture being placed at every junction of four plates. Lastly, the inner and outer integuments are connected together by a number of small straight cylindrical tubes or hollow spicula. The late Mr Salter regarded *Receptaculites* as belonging to the *Foraminifera*, and finding its nearest living ally in *Orbitolites*. Mr Billings, however, points out that it has some curious points of resemblance to the little seed-like "gemmule" of the Fresh-water Sponge; and he regards it as being on the whole a Sponge, having relationships with the *Foraminifera*. *Receptaculites* occurs in both Lower and Upper Silurian strata, as does the nearly-allied or identical genus *Ischadites*.

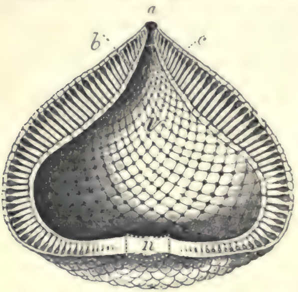


Fig. 20.—Diagram of the structure of *Receptaculites*, as it would be shown by a vertical section of a perfect specimen. *a* The aperture at the summit; *b* The inner integument; *c* The outer integument; *n* The usual position of the nucleus; *v* The great internal cavity. The unshaded bands running from the outer to the inner integument represent the tubes. (After Billings.)

CHAPTER VIII.

SUB-KINGDOM II.—CŒLENTERATA.

FOSSIL HYDROZOA.

SUB-KINGDOM II. CŒLENTERATA.—*Animals whose alimentary canal communicates freely with the general cavity of the body ("somatic cavity"), so that the body-cavity communicates with the outer world through the mouth. Body composed of two fundamental layers, an outer layer or "ectoderm," and an inner layer or "endoderm." The parts of the body, and especially the organs round the mouth, arranged in a star-like or radiated form.*

TABLE OF THE DIVISIONS OF THE CŒLENTERATA.

CLASS A. HYDROZOA.—The walls of the digestive sac not separated from those of the general body-cavity, the two coinciding with one another. Reproductive organs in the form of external processes of the body-wall.

Sub-class I. HYDROIDA (Hydroid Zoophytes).
- Order 1. *Hydrida.—Ex.* Hydra.
- Order 2. *Corynida.—Ex.* Tubularia.
- Order 3. *Thecaphora.—Ex.* Sertularia, Campanularia.

Sub-class II. SIPHONOPHORA (Oceanic Hydrozoa).
- Order 4. *Calycophoridæ.—Ex.* Diphyes.
- Order 5. *Physophoridæ.—Ex.* Physalia.

Sub-class III. DISCOPHORA (Jelly-fishes).
- Order 6. *Medusidæ.—Ex.* Ægina.

Sub-class IV. LUCERNARIDA (Sea-blubbers).
- Order 7. *Lucernariadæ.—Ex.* Lucernaria.
- Order 8. *Pelagidæ.—Ex.* Pelagia.
- Order 9. *Rhizostomidæ.—Ex.* Rhizostoma.

Sub-class V. GRAPTOLITIDÆ (Graptolites.)

CLASS B. ACTINOZOA.—Animal with a differentiated digestive sac opening below into the body-cavity, but separated from it by an intervening "perivisceral space," which is divided into compartments by a series of radiating vertical partitions or "mesenteries," to the faces of which the reproductive organs are attached.
- Order 1. *Zoantharia.—Ex.* Sea-anemones, Star-corals, Brain-corals.
- Order 2. *Alcyonaria.—Ex.* Sea-pens, Fan-corals, Sea-shrubs, Red-coral.
- Order 3. *Rugosa.—Ex.* Cyathophyllum.
- Order 4. *Ctenophora.—Ex.* Venus's Girdle.

The *Cœlenterata* appear to have commenced their existence in the Cambrian period, at which time both the great classes of the sub-kingdom were differentiated from one another. So far as we can judge, the Cœlenterate animals have attained their greatest development at the present day; but two large

groups (the *Graptolitidæ* and *Rugosa*) are wholly extinct, whilst the group of the Tabulate Corals is now much reduced in numbers. The above conclusion is further rendered uncertain by the existence in the sub-kingdom of some groups which, from their absence of hard parts, have left no traces of their past existence.

Fossil Hydrozoa.

Of the living orders of *Hydrozoa*, the Fresh-water Polypes (*Hydrida*) and the Oceanic Hydrozoa (*Calycophoridæ* and *Physophoridæ*) have left no traces of their former presence, as might have been anticipated from their want of hard structures. The order of the *Medusidæ* and the sub-class *Lucernarida* (Jelly-fishes and Sea-blubbers) are equally destitute of hard parts, and their absence from the palæontological record might have been confidently predicted. Curiously enough, however, traces of both groups have been detected in the fine-grained lithographic slates of Solenhofen and Eichstadt. Of the *Medusidæ*, the two living families of the *Æquoridæ* and *Trachynemidæ* have been recognised by their impressions; and an ancient member of the order *Rhizostomidæ* represents the *Lucernarida* in the same formation.* With these exceptions, however, the only living orders of *Hydrozoa* which have fossil representatives are the *Corynida* and *Thecaphora*, both of which possess a chitinous or horny integumentary skeleton. In neither case, however, can the evidence be said to be wholly free from suspicion.

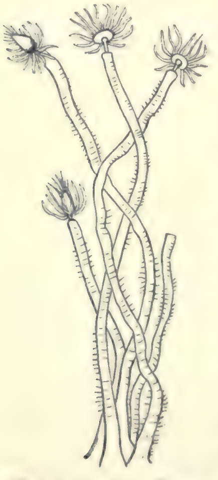


Fig. 21.—Corynida. Fragment of *Tubularia indivisa*, natural size.

I. Corynida or Tubularida (Pipe-Corallines.)—*Animal simple, consisting of a single polypite; or compound, consisting of several polypites united to one another by a common flesh or cœnosarc. The cœnosarc generally secretes a hard chitinous outer covering or "polypary;" but the separate polypites are never protected by cup-*

like expansions of the polypary. Type of the order, Tubularia (fig. 21).

Two genera, viz., *Palæocoryne* and *Corynoides*, have been referred to the *Corynida*, but in neither case is the reference free from doubt. *Palæocoryne* (fig. 22) is a minute organism which

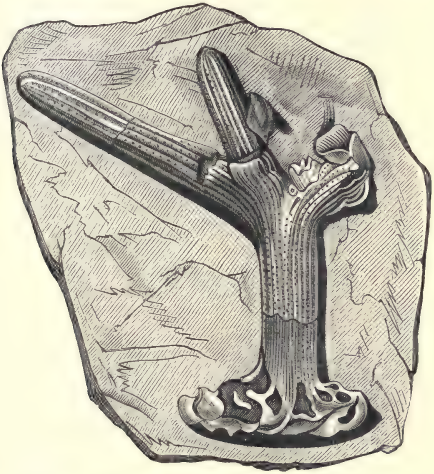


Fig. 22.—*Palæocoryne radiatum*, enlarged fifteen diameters. (After Duncan and Jenkins.)

was discovered by Dr Martin Duncan and Mr Jenkins growing attached to the margins of Lace-corals (*Fenestellæ*) in the Carboniferous Rocks of Scotland. Its base is expanded, with finger-like processes of attachment. From the base rises a short robust stem, which is marked with flutings and superficial granulations. The stem terminates in a single polypite, the mouth of which is surrounded by a single whorl of slender processes or "tentacles," in the centre of which is the mouth. The entire polypary, as above described, is "calcareous, dense, and ornamented." In one living form only (viz., *Bimeria*) is the polypary continued along the tentacles and upper part of the body of the polypite, and in this case the polypary is simply of the consistence of parchment. This peculiarity, therefore, with the possession of a *calcareous* polypary, renders the refer-

ence of *Palæocoryne* to the order *Corynida* not wholly free from doubt.

The genus *Corynoides* was proposed by the author for some singular fossils from the Lower Silurian Rocks of Scotland. Each consists of a cylindrical corneous tube (fig. 23), tapering towards the base, where it is furnished with two small spines, and expanding above into a species of toothed cup. *Corynoides* consists of a single polypite, and in this respect may be compared with some living *Corynida*. It would seem, however, not to have been attached to any foreign body—as all living *Corynids* are—and its true affinities are thus rendered uncertain.

Fig. 23.—*Corynoides calicularis*, enlarged. (Original.)

II. Thecaphora (or *Sertularida* and *Campanularida*).—*Animal compound, rooted and plant-like, consisting of numerous*

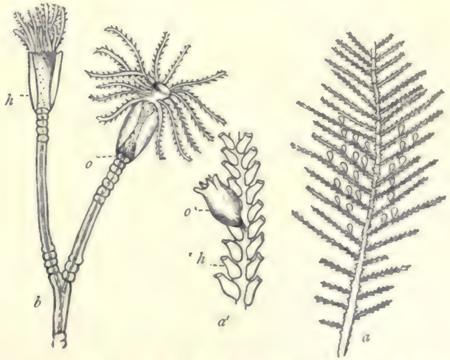


Fig. 24.—*a Sertularia (Diphasia) pinnata*, natural size; *a'* Fragment of the same enlarged, carrying a male capsule (*o*), and showing the hydrothecæ (*h*); *b* Fragment of *Campanularia neglecta* (after Hincks), showing the polypites contained in their hydrothecæ (*h*), and also the point at which the cœnosarc communicates with the stomach of the polypite (*o*).

polypites united by common flesh or cœnosarc. The cœnosarc is more or less branched, and secretes a strong chitinous investment or "polypary." The polypites are also protected within "hydro-

thecæ," or little cup-like expansions derived from the polypary. The process of reproduction is carried on by the development of the reproductive elements within horny urn-like sacs, which are of larger size than the "hydrothecæ," and are known as "ovarian capsules" or "gonothecæ" (often called "gonophores"). Type of the order, the Sea-fir (Sertularia, fig. 24).

As in the case of the *Corynida*, there is some uncertainty as to the existence of any fossil representatives of this order. No undoubted Sertularian, at any rate, is as yet known to the palæontologist; but there are several genera which may with more or less probability be referred to this place. The most important of these—as being those in which the reference is probably correct—are certain forms usually referred to the

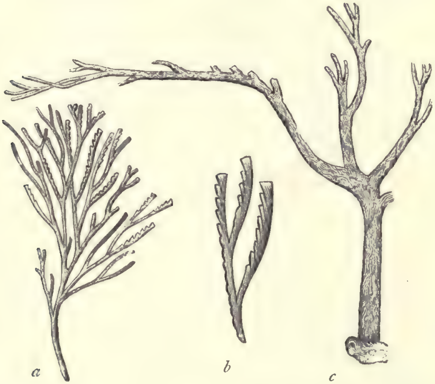


Fig 25 —*Dendrograpsus Hallianus*. *a* Portion of the frond, natural size; *b* Portion of a branch, enlarged; *c* The footstalk and some of the principal branches, natural size. (After Hall.)

Graptolitidæ, of which the genera *Dendrograpsus* and *Dictyonema* may be noticed in particular. The forms referred to *Dendrograpsus* are exclusively confined to the Upper Cambrian and Lower Silurian formations. They consist of plant-like spreading and branched growths, which are furnished with a strong footstalk (fig. 25). In all probability the organism was attached by the base of the footstalk to some foreign body, but no actual demonstration of this has as yet been obtained. The branchlets carry upon one side a series of

little chitinous cups or "cellules," each of which must have contained a polypite, and which agree with the similar structures of the Graptolites in partially overlapping one another; thus differing from the "hydrothecæ" of the Sertularians.

In *Dictyonema* (fig. 26) we have organisms resembling *Dendrograpsus* in many respects, but not possessing any foot-

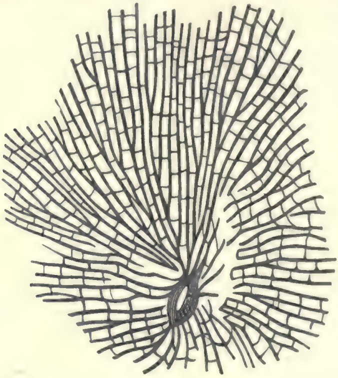


Fig. 26.—*Dictyonema retiforme*, Hall. (After Hall.)

stalk. The frond is branched and plant-like, and is fan-shaped or funnel-shaped in form. It is not certainly known whether the organism was attached by its base or not; but there is the strongest probability in favour of its having been fixed. The branches radiate from the base, running nearly parallel with one another, and often bifurcating. They are united to one another at short intervals by numerous, irregular, slender, transverse processes or dissepiments, and they bear small horny cups or "cellules" like those of the Graptolites. *Dictyonema* ranges from the Upper Cambrian to the Middle Devonian. The genus bears a close superficial resemblance to the *Fenestellæ* or Lace-corals (belonging to the *Polyzoa*); but the latter have a calcareous skeleton, and have no "cellules." Besides the above-mentioned genera, *Callograpsus* and *Ptilograpsus* may with great probability be referred to the *Sertularida;* as may, perhaps, be the obscure fossils *Buthograpsus* and *Thamnograpsus.* All these genera are Silurian or Upper Cambrian in age.

OLDHAMIA.—The singular fossils described under the genus *Oldhamia* may be noticed here, as they have been referred to the *Hydrozoa;* though their true nature is altogether uncertain. *Oldhamia* occurs in certain green and purple grits of Lower Cambrian age, at Bray Head, in Wicklow, Ireland. They occur in great abundance, matted together, and spreading over the surfaces of the strata. *Oldhamia antiqua*, the commonest species, consists of a central thread-like axis from which spring bundles or umbels of short radiating branches (fig. 27), at regular intervals. Each branch "is formed of a series of articulations marking the positions of minute cells" (E. Forbes). *Oldhamia* has been variously referred to the Sertularian Zoophytes, to the *Polyzoa*, and to the vegetable kingdom. The most probable conjecture would refer the genus to the calcareous seaweeds (Salter).

Fig. 27.—*Oldhamia antiqua*, natural size (after Salter). Cambrian.

III. SUB-CLASS GRAPTOLITIDÆ (Graptolites).—The Graptolites form a very large and important family of fossils which usually present themselves in the shape of horny linear bodies, toothed or serrated upon one or both sides, and often combined into more or less complex systems. If we disregard the genus *Dictyonema*, which is best referred elsewhere, the Graptolites have an extremely definite range in point of time, being exclusively confined to the Upper Cambrian and Silurian deposits. They attain their maximum of development in the Upper Cambrian Rocks (Quebec group of Canada and Skiddaw Slates of England), are abundantly represented in the Lower Silurian, and die out altogether before the close of the Upper Silurian period.

Excluding the genera *Dictyonema*, *Dendrograpsus*, *Ptilograpsus*, and *Callograpsus*, the *Graptolitidæ* may be defined by the possession of a compound polypary, consisting of a tubular chitinous investment enclosing the cœnosarc, giving origin to numerous cup-like "cellules" or "hydrothecæ," each of which protected a polypite. The polypary was free, and was not attached to any foreign body; and the polypites were not separated from the cœnosarc by any partition. Lastly, the poly-

pary was almost always strengthened by a chitinous rod or fibre, which is termed the "solid axis," and which is somewhat analogous to the chitinous rod described by Dr Allman in the singular Polyzoön, *Rhabdopleura*.

From the above definition, it will be seen that the Graptolites agree with the living Sertularians in possessing a corneous polypary, which not only invests the cœnosarc, but is expanded into little cups or "hydrothecæ," within which each polypite is protected. The Graptolites, however, differ from the Sertularians in the fact that the polypary was unattached, and apparently free-floating, whilst it has not, except in a few cases, anything like the plant-like appearance of the latter. Further, the hydrothecæ of the Graptolites, except in the genus *Rastrites*, always more or less overlap one another; whereas those of the Sertularians are not in contact. Lastly, no Sertularian exhibits any structure which can be compared with the "solid axis" of the Graptolites.

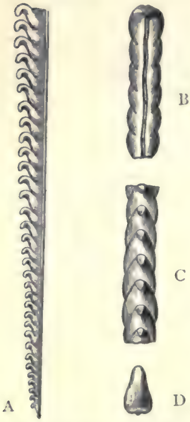


Fig. 28.—Morphology of *Graptolites priodon*. A, *Graptolites priodon*, Bronn, preserved in relief: lateral view slightly enlarged. B, Dorsal view of a fragment of the same species: considerably enlarged. C, Front view of a fragment of the same, showing the mouths of the cellules: much enlarged. D, Transverse section of the same. All from the base of the Coniston Flags. (Original.)

Taking such a simple Graptolite as *G. priodon* (fig. 28), or *G. sagittarius* (fig. 29, A), as the type of the subclass, the polypary is seen to consist of three elements, which are known as the "solid axis," the "common canal," and the "cellules." The "solid axis" is a cylindrical fibrous rod which gives support to the corneous and flexible polypary. The term "solid" is probably a misnomer; for it was almost certainly hollow, and filled with living material. It appears to be absent in the genus *Rastrites*, and in *Retiolites Geinitzianus*, but some uncertainty rests upon this point. As a very general rule, it is prolonged as a longer or shorter naked rod beyond one or both ends of the polypary, and either extension may be more or less dilated. Its basal prolongation, with or without an accompanying extension of the common canal, is termed the "radicle," or "initial point," as marking the organic base of the frond.

The "common canal" is the tube in which the cœnosarc

was enclosed; but it commonly appears, in compressed specimens, merely as a vacant space between the "cellules" and the solid axis. The common canal gives origin, by a process of budding, to the "cellules" or "hydrothecæ," which are little horny cups for the reception of the polypites. Each cellule

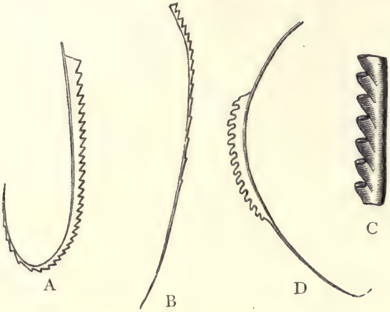


Fig. 29.—A, Young individual of *Graptolites sagittarius*, His., showing the slender curved base of the frond, and the extension of the axis beyond its opposite end; B, Base of another individual of the same, in which there is an extremely long "radicle;" C, Fragment of *G. sagittarius*, much enlarged to show the cellules—from a specimen in relief; D, Specimen of *Graptolites Clingani*, Carr., showing the distal and proximal extensions of the axis.

rests by its base upon the common canal, is separated from its neighbours by "cell-partitions," and opens at its apex by a distinct aperture or "cell-mouth," through which the polypite could exsert its tentaculate head.

The reproductive process appears, in some cases, at any rate, to have been carried on by the formation at certain seasons of horny capsules, of much greater size than the cellules, within which the generative elements were matured. In some cases these "ovarian vesicles" have been found actually attached to the fronds of Graptolites. In other cases, as described by the writer, we find numerous bell-shaped horny capsules (fig. 30), each with a little spine at its summit, scattered through the rock in which the Graptolites occur, but only doubtfully attached to the fronds of the latter. These we may infer to have been "ovarian vesicles;" but they differ from the bodies so called in the Sertularians in becoming detached from the parent colony.

Two leading types may be distinguished amongst the Grap-

tolites, which are termed respectively "monoprionidian" and "diprionidian." The monoprionidian graptolites, such as *G. priodon* (fig. 28), are distinguished by the fact that the polypary,

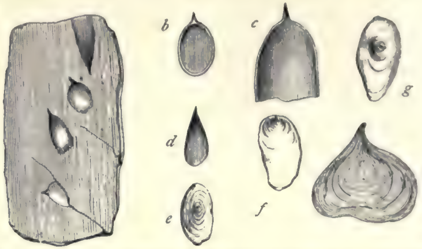


Fig. 30.—Supposed "Ovarian Capsules" or reproductive buds of Graptolites.

whether simple or branched, possesses but a single row of cellules or "hydrothecæ." In the diprionidian forms, on the other hand, as in *Diplograpsus* (fig. 35), the polypary possesses a row of cellules on each side. It is noticeable that the diprionidian graptolites, with rare exceptions, are confined to the *Lower* Silurian and Cambrian Rocks; whilst the monoprionidian forms range from the Cambrian to the summit of the *Upper* Silurian series.

At least sixteen genera of Graptolites, as here restricted, are known to science; but it will be sufficient to give the diagnostic characters of a few of the commonest and more important types. In the genus *Graptolites* (figs. 28, 29), the polypary is simple, linear, possessing but a single row of cellules on one side, and commencing by an attenuated, usually curved, base.

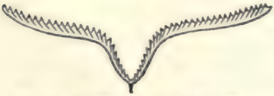


Fig. 31.—*Didymograpsus V-fractus.* Upper Cambrian (Skiddaw Slates).

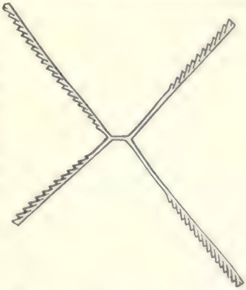


Fig. 32.—*Tetragrapsus quadribrachiatus* (after Hall). Upper Cambrian (Skiddaw and Quebec groups).

Species of this genus are found from near the base of the

Lower Silurian series to the very summit of the Upper Silurian deposits.

In the genus *Didymograpsus* (fig. 31), the polypary consists of two simple monoprionidian branches, which spring from a common point, which is almost invariably marked by a small spine-like "radicle." The genus attains its maximum in the Quebec group of Canada and Skiddaw slates of England (Upper Cambrian), and is well represented in the earlier portion of the Lower Silurian period (Llandeilo Rocks); but no species of the genus is known as late as the Upper Silurian period.

In the genus *Tetragrapsus* (fig. 32), the polypary consists of four simple monoprionidian branches, springing from a central non-celluliferous connecting process, which bifurcates at each end. The celluliferous branches do not subdivide, and the base may be enveloped in a peculiar corneous "disc," as will be immediately described in the genus *Dichograpsus*. The species of *Tetragrapsus* are exclusively confined to the Skiddaw and Quebec groups (Upper Cambrian).

In the genus *Dichograpsus* there are more than four (usually eight) simple monoprionidian branches, which arise from the same number of divisions of a non-celluliferous basal process. In many cases the divisions of the basal connecting process (fig. 33), are enveloped

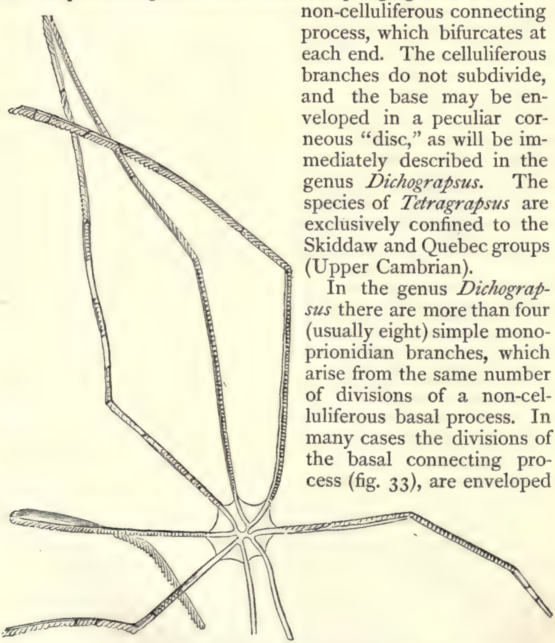


Fig. 33.—*Dichograpsus octobrachiatus*, showing the central disc (after Hall). Skiddaw and Quebec groups.

in a species of corneous "disc" or plate, which is believed to have been composed of two laminæ. The functions of this disc are doubtful; but it has been compared with the "float" or buoy of the *Physophoridæ*, an order of the Oceanic Hydrozoa.

In the genus *Rastrites* (fig. 34), the polypary consists of a

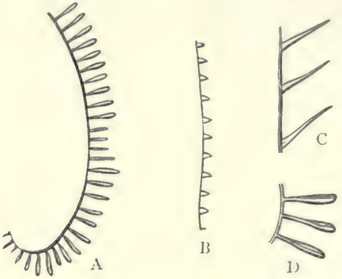


Fig. 34. Morphology of Rastrites.—A, *Rastrites peregrinus*, Barr., from the Mudstones of the Coniston Series, enlarged. B, *Rastrites capillaris*, Carr., from the Upper Llandeilo Shales of Dumfriesshire, enlarged. C, Fragment of *Rastrites Linnæi*, Barr., from the Coniston Mudstones, enlarged. D, Fragment of *R. peregrinus*, greatly enlarged, showing the impressed line running up the centre of each cellule. (Original.)

slender axial tube, giving off on one side a series of linear tubular cellules or "hydrothecæ," which are free throughout their entire length. The genus differs from all the other Graptolites, in the fact that the cellules do not overlap one another, but are free through their whole length, whilst it is very doubtful if a true "solid axis" is present. In Britain and North America the species of *Rastrites* are exclusively confined to the Lower Silurian Rocks, but in Bohemia they pass up into the lowest beds of the Upper Silurian.

In the genus *Diplograpsus* (fig. 35), the polypary consists of two simple monoprionidian stipes, firmly united to one another, back to back. The frond, therefore, is "diprionidian," or carries cellules on both sides. The solid axis is usually prolonged beyond the base of the polypary as a longer or shorter process or "radicle," which is often flanked by lateral spines. The solid axis is also almost invariably prolonged beyond the opposite or "distal" end of the polypary as a naked rod. In the nearly-allied genus *Climacograpsus*, the structure is much as above described, but the cellules have such a structure that

their mouths appear to be sunk below the general surface of the polypary, forming a row of rounded or quadrangular openings on each side. Both *Diplograpsus* and *Climacograpsus* range in Britain and North America from the Upper Cambrian to the summit of the Lower Silurian series; but in Bohemia they rise into the lower portion of the Upper Silurian deposits. In the genus *Dicranograpsus* the polypary is at first diprionidian, but soon splits into two monoprionidian branches which carry the cellules along their outer margins. The genus is exclusively Lower Silurian. Lastly, the beautiful genus *Phyllograpsus* may be regarded as composed of two *Diplograpsi* placed at right angles to one another. It is exclusively confined to the Skiddaw and Quebec Rocks.*

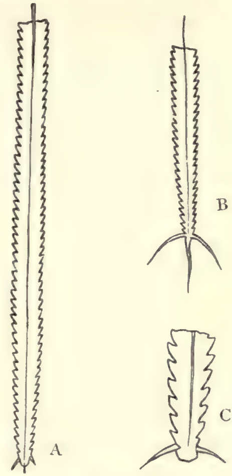


Fig. 35.—A, *Diplograpsus pristis*, His., slightly enlarged, showing the normal condition of the base; B, Another example of the same, slightly enlarged, showing a long radicle, and long lateral spines; C, Another of the same, enlarged, showing lateral spines, succeeded proximally by a small bulb, but showing no true radicle. (Original.)

* The Student, desirous of fuller information on this subject, may consult the author's 'Monograph of the British Graptolitidæ,' Part I., General Introduction; where full details are given as to the morphology and affinities of these singular fossils.

CHAPTER IX.

FOSSIL ACTINOZOA.

Of the living groups of the *Actinozoa* (see Table, p. 73), the *Ctenophora* and the Sea-anemones (*Zoantharia malacodermata*), from their absence of hard parts, are unknown in a fossil condition. The remaining groups—viz., the *Zoantharia sclerobasica*, *Zoantharia sclerodermata*, *Alcyonaria*, and *Rugosa*—secrete a hard skeleton, which is known by the general name of the "coral"

or "corallum." All these groups, therefore, are known as fossils; but they are of very unequal importance. The *Zoantharia sclerobasica* and *Alcyonaria* are known by very few fossil representatives, and require to be little more than mentioned. The *Zoantharia sclerodermata* and *Rugosa*, on the other hand, have left very numerous and interesting traces of their former existence — the latter being almost altogether extinct, — and both will require to be noticed at some length. Regarded as a whole, the class of the *Actinozoa* appears, so far as we yet know, to have commenced its existence in the Upper Cambrian period, and to have attained its maximum of development at the present day.

ORDER I.—ZOANTHARIA.

Tentacles simple, rounded; soft parts in multiples of five or six.

Sub-order 1. *Zoantharia malacodermata.—Ex.* Sea-anemone.
,, 2. *Zoantharia sclerobasica.—Ex.* Antipathes.
,, 3. *Zoantharia sclerodermata.—Ex.* Reef-building Corals.

A. ZOANTHARIA MALACODERMATA.—Though, from their soft nature, unknown in a fossil condition, the Sea-anemones merit a brief description here, as they may be taken as the types of the order, and as the somewhat complicated structure of the sclerodermic coral will thereby be rendered much more intelligible.

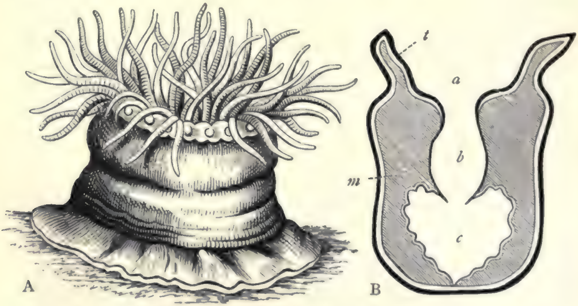


Fig. 36.—A, *Actinia mesembryanthemum*, one of the Sea-anemones (after Johnston). B, Section of the same, showing the mouth (*a*), the stomach (*b*), and the body-cavity (*c*).

The body of a Sea-anemone (fig. 36) is a truncated cone, or a short cylinder, termed the "column," and is of a soft,

leathery consistence. The two extremities of the column are termed respectively the "base" and the "disc,"—the former constituting the sucker, whereby the animal attaches itself at will, whilst the mouth is situated in the centre of the latter. In a few cases (*Cerianthus* and *Peachia*) the centre of the base is perforated, but the object of this arrangement is unknown. Between the mouth and the circumference of the disc is a flat space, without appendages of any kind, termed the "peristomial space." Round the circumference of the disc are placed numerous tentacles, usually retractile, arranged in alternating rows, and amounting to as many as 200 in number in the common *Actinia.* The tentacles are tubular prolongations of the ectoderm and endoderm, containing diverticula from the somatic chambers, and sometimes having apertures at their free extremities. The mouth leads directly into the stomach, which is a wide membranous tube, opening by a large aperture into the general body-cavity below, and extending about half-way between the mouth and the base. The wide space between the stomach and column-wall is subdivided into a number of compartments by radiating vertical lamellæ, termed the "primary mesenteries," arising on the one hand from the inner surface of the body-wall, and attached on the other to the external surface of the stomach. As the stomach is considerably shorter than the column, it follows that the inner edges of the primary mesenteries below the stomach are free; and these free edges, curving at first outwards and then downward and inwards, are ultimately attached to the centre of the base. Besides the primary mesenteries, there are other lamellæ which also arise from the body-wall, but which do not reach so far as the outer surface of the stomach, and are called "secondary" and "tertiary" mesenteries, according to their breadth. The reproductive organs are in the form of reddish bands, which contain ova and spermatozoa, and are situated on the faces of the mesenteries.

B. Zoantharia Sclerobasica. — The members of this group are all composite organisms, consisting of numerous polypes, each of which has essentially the structure of a small Sea-anemone, united together by a common organised medium or "cœnosarc" (fig. 37). Each polype has six tentacles, and the entire organism is supported by an internal skeleton or "corallum." The coral is horny, and it is what is called "sclerobasic;" that is to say, it forms an internal axis, over which the cœnosarc is spread, much as the bark encloses the wood of a tree. As the polypes are sunk in the cœnosarc, and as this simply forms a rind for the coral, it follows that

the polypes are *outside* the corallum. In other words, the polypes take no part in the secretion of the corallum; but this is deposited solely by the cœnosarc or common flesh by which the polypes are connected together.

Fig. 37.—Part of a living stem of *Antipathes anguina*, of the natural size. (After Dana.)

The *Zoantharia sclerobasica* are not known as occurring in either the Palæozoic or Mesozoic period. They appear for the first time in Tertiary deposits, and the genus *Antipathes* is represented in strata of Miocene age.

C. Zoantharia Sclerodermata. — This group includes most of the so-called "corals," and is of very high geological importance. All the members of this group secrete a skeleton or "corallum," and this is necessarily the only part of the animal with which the palæontologist has to deal; so that it becomes necessary to enter into its structure at some length. The animal itself, in the *Zoantharia sclerodermata*, in its essential structure resembles a sea-anemone; but it very often has the power of repeating itself by budding (gemmation) or cleavage (fission), so that from a simple it becomes a compound organism. It may therefore consist of a single "polype," or of many similar polypes united by a common flesh or "cœnosarc." The corallum is what is called "sclerodermic," its essential peculiarity being that it is secreted by the polype or polypes. The sclerodermic coral, in fact, is an actual calcification of part of the tissues of the polype. When, therefore, we have a *simple* coral, produced by a simple member of this group (as in fig. 38), we have clearly to do with nothing but skeletal structures produced in the interior of the polype itself. When, on the other hand, we have a *compound* sclerodermic coral to deal with, we have usually more than this. We have, namely, two parts or elements of the coral to consider: 1. The parts of the coral secreted by each individual polype; and, 2. The parts secreted by the cœnosarc which unites all the polypes into an organic whole. A compound coral may be theoretically regarded, therefore, as consisting of a greater or less number of simple corals, such as the preceding, united together by a greater or less quantity of calcareous matter

secreted by the cœnosarc (fig. 40). The entire compound corallum consists, therefore, of a greater or less number of

Fig. 38.—*Petraia calicula.* Lower Silurian.

Fig. 39.—*Zaphrentis Stokesi.* Lower Silurian.

"corallites" bound together by a calcareous basis, which is secreted by the cœnosarc, and is called the "cœnenchyma."

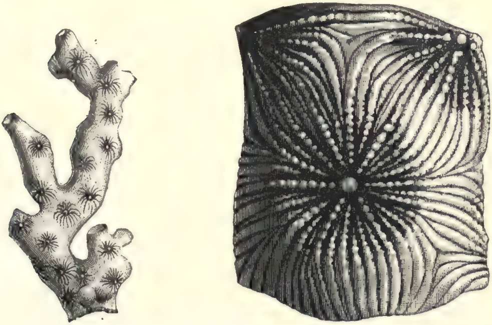


Fig. 40.—*Synhelia Sharpeana.*

In practice, however, this theoretical view of the subject is not always borne out. The compound corallum may, and often does, consist (as in fig. 41) of a number of corallites produced

by budding or cleavage from a primitive corallite, having their outer walls closely amalgamated, but not sunk in any general cœnenchyma. In other cases, the cœnenchyma, though not actually absent, is very much reduced in quantity.

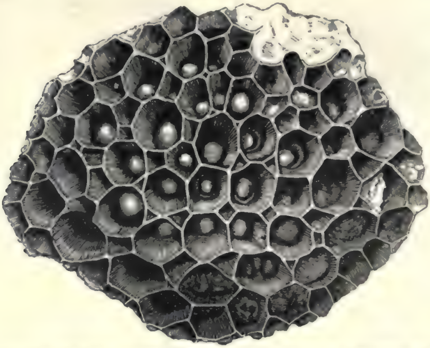


Fig. 41.—*Michelinia convexa* (D'Orbigny). A compound sclerodermic Coral. Devonian.

To comprehend the more intimate structure of a sclerodermic coral, we may take a single "corallite" of a composite form—or, better, the simple corallum secreted by a form which never repeats itself by gemmation or cleavage (fig. 42). Such a coral consists of an outer wall, which encloses an internal space or chamber, and which assumes very various forms. We may, however, take the simplest and commonest form, in which the coral is conical or turbinate in shape (fig. 42). The outer wall of this cone is called the "theca," and it encloses a space which is variously subdivided below, but which has the form of a shallower or deeper conical cup towards its summit. This vacant space is called the "calice," and in the living state it contains the stomachal sac of the polype. The space below the calice is broken up into a number of vertical compartments or "loculi,"

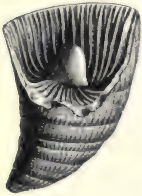


Fig. 42. — *Cyathaxonia Dalmani*. A simple sclerodermic coral, showing the theca, with its costæ, the calice, with the columella in its centre, and the septa. A portion of wall of the theca is broken, in order to show the interior of the calice.

by a series of upright partitions or "septa," which spring from the inner surface of the theca, and advance toward its centre. Very commonly some of the septa unite centrally with a median calcareous rod, which extends vertically from the bottom of the theca to the bottom of the calice (sometimes projecting into the latter), and which is called the "columella." The columella, however, is often wanting, or a spurious one may be formed by the twisting together or coalescence of the inner edges of the septa. In rare cases, also, the septa themselves are wanting. The septa, further, are of different breadths. A certain number (fig. 43) extend quite to the

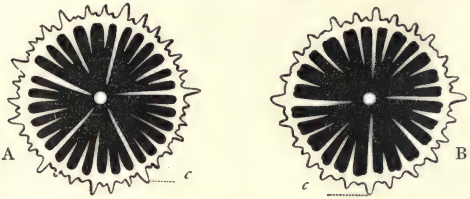


Fig. 43.—Diagrammatic sections of corals. A, Section of sclerodermic coral, showing five primary septa, the columella, and costæ (*c*); B, Section of Rugose coral, showing four primary septa. Between the primary septa are seen the secondary and tertiary septa.

centre of the coral, where they meet the columella (when this is present). These are called the "primary septa." Others, however, fall short of the columella by a greater or less distance; and these are called "secondary" and "tertiary" septa, according to their breadth.

The above is the essential structure of the typical form of a simple sclerodermic coral, and it is easy to see that it is produced by the calcification, or conversion into carbonate of lime, of the *lower* portion of a polype similar in structure to an ordinary Sea-anemone. The "theca" of the coral corresponds to, and is secreted by, the "column-wall" or general wall of the body of the polype. The "septa," again, correspond with the "mesenteries," and, like them, are "primary," "secondary," or "tertiary," according as they reach the centre or fall short of it by a greater or less distance. We must remember, however, that it is only the *inferior* half of the body of the polype which is thus calcified. The tentacular disc and mouth are placed at some distance above the upper margin of the theca, and the digestive sac occupies the calice; whilst

the whole of the space comprised within the theca is lined by the endoderm, and the whole of its outer surface is covered by the ectoderm.

Whilst the above gives the fundamental structure of a simple sclerodermic corallum, there are some additional details which are of sufficient importance to demand special notice. The septa in the coralla of the *Zoantharia sclerodermata*, like the mesenteries of the living animal, are in multiples of *five* or *six*. It is not common, however, to find the septa so few as would be represented by these fundamental numbers. Commonly, in progress of growth, fresh septa are formed between those originally present, until there may be several "cycles" of septa (fig. 43).


Fig. 44. — *Turbinolia sulcata*. The upper figure shows the exterior of the theca with the costæ. The lower figure shows the calice, with the columella and primary and secondary septa. Eocene.

The septa may be considered as being continued, in many cases, through the theca, and beyond its external surface. The outer surface of the theca thus comes to be covered with a series of vertical ridges or ribs, which are termed the "costæ" (fig. 43, *c*, and fig. 44). The costæ vary much as to the distance by which they are separated from one another, and as to their breadth, their solidity, and their ornamentation with spines, tubercles, or teeth.

In some cases the outer surface of the theca is more or less covered by a thicker or thinner envelope of calcareous matter, constituting what is termed the "epitheca." In some cases, as in the genus *Montlivaltia* (fig. 45), the epitheca is very highly developed, and forms a dense covering, but it is often extremely thin. It varies much as to the extent to which it is applied to the theca; and it may be smooth, or may be marked by concentric or encircling ridges.

The chief remaining structures which may be noticed are what are called "pali," "dissepiments," and "tabulæ." *Pali* are "small processes which exist between certain septa and the columella. They generally arise from the base of the visceral cavity, or close to it, and pass upwards, united by one

edge to the columella, and by the other to the inner end or margin of the septa. When there is no columella, they are adherent to the septa, present a free edge to the cavity in the axis of the corallum, and arise with the septa" (Duncan). The *dissepiments* are incomplete horizontal plates which grow from the sides of the septa, stretching from one septum to another, and more or less interfering with the continuity of the loculi, and breaking them up into a series of cells. The loculi may thus, when the dissepiments are numerous, become more or less completely *vesicular*. Lastly, the *tabulæ* (fig. 46) are transverse plates or floors running at right angles to the axis of the corallite, and dividing the theca into so many horizontal compartments or stories, each of which is vertically subdivided by the septa, when these exist. Very generally, however, the septa are absent when the coral is "tabulate."

Fig. 45.—*Montlivaltia caryophyllata*, showing the greatly-developed epitheca covering the lower part of the coral. Great Oolite.

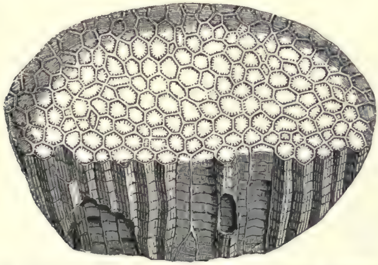


Fig. 46.—*Columnaria alveolata*, showing the corallites partitioned off into stories by tabulæ. Silurian.

Gemmation and Fission amongst Corals.—Compound Corals, as before remarked, are produced by a process of budding (gemmation) or cleavage (fission) from an originally simple form, or by a combination of both these processes. Most commonly, the compound sclerodermic coral consists of a number of "corallites," each produced by a separate polype, and of a common calcareous basis, or "cœnenchyma," secreted by the cœnosarc. There may, however, be no cœnosarc, and

consequently no cœnenchyma; and the compound coral may consist simply of a congeries of corallites directly united to, or springing from, one another.

Three chief forms of gemmation may be distinguished amongst the compound *Zoantharia*—viz., *basal*, *parietal*, and *calicular*.

In basal gemmation the mode of increase is by means of a rudimentary cœnosarc, which is put forth by the original polype, and from which the young polype-buds are produced. It "affords very different products according as the cœnosarc remains soft, or deposits a cœnenchyma; appears under the form of stolons, or of stouter connecting stems; or even spreads out in several directions as a continuous horizontal expansion;" in which last case the youngest polypes are, of course, those nearest to the periphery of the mass.

The parietal mode of gemmation is the commonest, and it gives rise chiefly to dendroid, or tree-like, corals. In this method the buds are produced from the sides of the original polype, and they often repeat the process indefinitely.

Calicular gemmation is not known to occur in any recent coral, but it was a common mode of increase amongst extinct forms. In this method "the primitive polype sends up from its oral disc two or more similar buds; these, in their turn, produce other young polypes, and thus the process is repeated until an inverted pyramidal mass of considerable size is produced, all the parts of which rest upon the narrow base of the first budding polype" (fig. 47).

Fig. 47. — Calicular gemmation as seen in *Lonsdalea floriformis*. Upper Silurian.

Fission in the *Actinozoa* differs from gemmation chiefly in the fact, that the polypes produced fissiparously resemble one another in organisation, and often in size, as soon as they become distinct. In gemmation, on the other hand, the polype-bud consists primarily of a mere process of ectoderm and endoderm, enclosing a cæcal process of the somatic cavity, and a mouth and other structures are at first wanting. Amongst the coralligenous *Actinozoa* fission is usually effected by "oral cleavage," the divisional groove commencing at the oral disc, and deepening to a certain extent,

the proximal extremity always remaining undivided. More rarely, fission "is effected by the separation of small portions from the attached base of the primitive organism, whose form and structure they subsequently, by gradual development, tend to assume."

"The coral structures which result from a repetition of the fissiparous process are of two principal kinds, according as they tend most to increase in a *vertical* or in a *horizontal* direction. In the first of these cases the corallum is *cæspitose*, or tufted, convex on its distal aspect, and resolvable into a succession of short diverging pairs of branches, each resulting from the division of a single corallite." In the second case the coral becomes *lamellar*. "Here the secondary corallites are united throughout their whole height, and disposed in a linear series, the entire mass presenting one continuous theca." Both these forms of corallum "are liable to become *massive* by the union of several rows or tufts of corallites throughout the whole or a portion of their height. An illustration of this is afforded by the large *gyrate* corallum of *Meandrina*, over the surface of whose spheroidal mass the calicine region of the combined corallites winds in so complex a manner as at once to suggest that resemblance to the convolutions of the brain which its popular name of Brain-stone Coral has been devised to indicate." (Greene, 'Manual of Cœlenterata,' p. 185 *et seq.*)

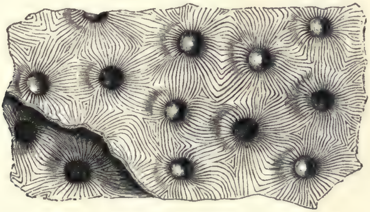


Fig. 48.—*Phillipsastræa Verneuilli.* From the Devonian (Corniferous Limestone) of N. America.

Deep-sea Corals and Reef-builders.—At the present day, as has been specially insisted on by Dr Martin Duncan, we find two great groups of the Sclerodermic *Zoantharia*—viz., those which inhabit tolerably deep water, and those which build the great masses of coral which are known as "coral-reefs." The deep-sea corals, though often attaining, as individuals, a considerable size, and though often compound,

never form massive aggregations or "reefs." This is due to the fact that, when composite, the separate corallites are not united together by a lax cellular cœnenchyma, so that the colony cannot increase to an indefinitely large size. The deep-sea corals seem to have existed in all the great geological periods, from the Silurian upwards. The chief genera of this group at the present day are *Caryophyllia*, *Balanophyllia*, *Flabellum*, *Desmophyllum*, and *Sphenotrochus*, amongst the simple forms; and *Lophohelia*, *Amphihelia*, *Dendrophyllia*, and *Astrangia*, amongst the compound forms.

The reef-building corals, when simple, are provided with special structures which enable the polypes to grow rapidly. The great majority of the reef-builders, however, are compound, and owe the large size to which they attain to the fact that the corallites are mostly united by a loose cellular cœnenchyma. The chief genera of reef-building *Zoantharia* in Mesozoic, Kainozoic, and Recent times, are *Mæandrina*, *Madrepora*, *Porites*, *Astræa*, *Millepora*, *Heliopora*, *Cycloseris*, *Trochoseris*, *Heliastræa*, *Solenastræa*, *Pachyseris*, *Turbinaria*, and *Astræopora*; but many others might be mentioned.

Amongst the more ancient examples of coral-reefs may be mentioned the Wenlock Limestone of the Upper Silurians in England, some of the Devonian Limestones in North America, and parts of the Carboniferous Limestone in various parts of the world. In Mesozoic times coral-reefs existed towards the close of the Trias in Western Europe, and largely in Oolitic times both in Western Europe and in England. In the earlier portion of the Tertiary period, again, vast coral-reefs were formed in Central and Southern Europe, in Egypt, Syria, and Arabia, and in parts of India.

Divisions and Distribution in Time of the Zoantharia Sclerodermata.—The *Zoantharia sclerodermata* are divided into the four following groups, founded upon the characters of the corallum:—

1. *Tabulata.*—Septa rudimentary, or entirely absent; tabulæ well developed and dividing the space included within the theca (the "visceral chamber") into a number of stories (fig. 46).

2. *Perforata.*—Septa well developed; dissepiments rudimentary; no tabulæ; calcareous tissue of the coral ("sclerenchyma") *porous.*

3. *Aporosa.*—Septa well developed, lamellar; no tabulæ; calcareous tissue of the corallum ("sclerenchyma") *compact* and imperforate.

4. *Tubulosa.*—Septa indicated by mere striæ; thecæ pyriform, occasionally united by a basal cœnenchyma (fig. 94).

As regards the distribution in time of the above four groups, the Tabulate Corals attain their maximum in the Palæozoic period, being well represented in the Silurian, Devonian, and Carboniferous formations. The family *Thecidæ* is exclusively Silurian; but the familiar *Seriatoporidæ*, *Favositidæ*, and *Milleporidæ* survived to the present day; though there are many breaks in our knowledge of their course.

The *Perforata* are, on the whole, most abundant in Mesozoic and Cainozoic strata, and attain their maximum at the present day. In the Palæozoic series the group is represented by *Protarea* (Silurian) and *Pleurodictyum* (Devonian), both belonging to the family of the *Poritidæ*. The great family of the *Madreporidæ*, on the other hand, did not make its appearance till the Cretaceous period.

The *Aporosa* are almost exclusively confined to the Mesozoic, Kainozoic, and recent periods, attaining their maximum at the present day. In the Palæozoic period the group is only represented by the Silurian genus *Palæocyclus*, belonging to the *Fungidæ*. At the commencement of the Mesozoic period, in the Trias, appears for the first time the great family of the *Astræidæ*, so largely represented at the present day. Almost all the Jurassic Corals belong to the *Aporosa*, and the two families of the *Turbinolidæ* and *Oculinidæ* make their first appearance here. In the Cretaceous Rocks the *Aporosa* are largely represented, the family *Astræidæ* being particularly rich in generic forms. In the Tertiary period the group is also well represented.

The *Tubulosa*, comprising the single family of the *Auloporidæ*, are exclusively Palæozoic. In the Devonian period, and doubtfully in the Silurian, we have the genus *Aulopora* (fig. 49); and in the Carboniferous Rocks occurs the genus *Pyrgia*. There is, however, reason to believe that these genera have been founded upon the young and immature forms of other corals.

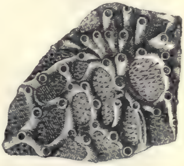


Fig. 49.—*Aulopora serpens.* Devonian.

ORDER II. RUGOSA.—The members of this order are almost entirely extinct, and, with the exception of *Holocystis elegans* from the Lower Cretaceous rocks, and a few more modern forms, are not known to occur in deposits younger than the Palæozoic epoch. With the soft parts of the *Rugosa* we are, for the most part, entirely unacquainted, and the definition of the order must therefore be founded upon the characters of the corallum. The corallum in the *Rugosa* is highly de-

veloped, sclerodermic, with a true theca, and often presenting both septa and tabulæ combined. The septa are in multiples of *four* (fig. 43), unlike the recent sclerodermic coralla, in which they are in multiples of *five* or *six*. There is, further, no true cœnenchyma. Some of the Rugosa are simple; but others are composite, increasing either by parietal or by calicular gemmation.

The Palæozoic corals (figs. 50-55), with hardly an exception,

PALÆOZOIC CORALS.

Fig. 50.—*Syringopora retiformis.* A Silurian Tabulate Coral.

Fig. 51.—*Syringopora verticillata.* Silurian.

Fig. 52.—*Syringopora Dalmani.* Silurian.

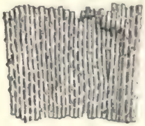


Fig. 53.—*Syringopora compacta.* Silurian.

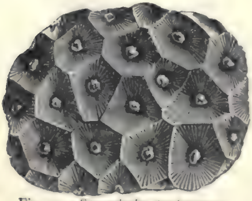


Fig. 54.—*Strombodes pentagonus.* A Silurian Rugose Coral.

Fig. 55.—*Strombodes gracilis.* Silurian.

belong either to the *Rugosa* or to the Tabulate division of the *Zoantharia sclerodermata*. The former are readily distinguishable from the latter in having well-developed septa, as a rule, and in invariably having their septa in multiples of four. Until

quite recently it was believed that all the *Rugosa* were Palæozoic, with the exception of the genus *Holocystis*, represented in the Cretaceous period (Upper Greensand) by the single species *H. elegans*. Recent researches, however, have brought to light the existence in our present seas of at least two genera (*Haplophyllia* and *Guynia*) which belong to the Rugose family of the *Cyathaxonidæ;* and certain Tertiary Rugose Corals have also been described (Martin Duncan). As the *Rugosa* are in no fundamental structural character to be distinguished from the *Zoantharia sclerodermata*, save in the number of their septa, there would thus seem to be no good ground for maintaining that there is any essential difference between the Palæozoic corals and those of more modern times.

Recently it has been shown that some very abnormal Rugose corals were provided with a lid or operculum, closing the mouth of the calice. In the genus *Calceola* (fig. 56), formerly referred to the *Brachiopoda*, and very abundant in certain parts of the Devonian system, the operculum consisted of a single valve or piece. In *Goniophyllum* four valves were present, and in *Cystiphyllum prismaticum* there were four or more valves in the operculum. It is worthy of notice that some recent corals (species of *Primnoa*, *Paramuricea*, and others) exhibit also a more or less complete operculum. According to Professor Agassiz, the *Rugosa* and the *Tabulate* division of the *Zoantharia* ought not to be considered as belonging to the *Actinozoa*, but should be placed amongst the *Hydrozoa*. This radical change, however, cannot be accepted without the production of very conclusive evidence in its favour. A strong argument against referring the Rugose and Tabulate Corals, as proposed by Agassiz, to the *Hydrozoa*, is their possession in most cases of well-developed *septa*, implying, of course, the existence in the living animal of *mesenteries*, structures which are wholly wanting in the *Hydrozoa*.

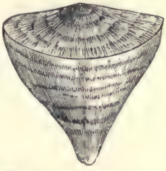


Fig. 56. — *Calceola sandalina.* An operculate Rugose Coral. Devonian.

As regards the distribution in time of the families of the *Rugosa*, the most important group is that of the *Cyathophyllidæ*, which is abundantly represented in the Silurian, Devonian, and Carboniferous Rocks. The family *Cyathaxonidæ* is Silurian and Carboniferous, and is represented by two living genera. The family *Cystiphyllidæ* is Silurian and Devonian. Lastly, the family *Stauridæ* is represented in the Silurian Rocks by the genus *Stauria*, in the Devonian Rocks by the genus

Metriophyllum, in the Permian Rocks by the genus *Polycœlia*, and in Tertiary deposits by the genus *Conosmilia*.

Appendix giving a Tabular View of the Divisions of the Zoantharia Sclerodermata and Rugosa (after Milne-Edwards and Jules Haime).

A. The *Zoantharia Sclerodermata* are defined by the possession of a sclerodermic corallum, the parts of which are arranged in multiples of five or six. Septa generally well developed, but not combined, as a rule, with tabulæ.

The following chief divisions of the *Zoantharia Sclerodermata* are, with few alterations, those adopted by the above-mentioned authorities:—

I. Tabulata. — Septa rudimentary or absent; tabulæ well developed, dividing the visceral chamber into a series of stories.

1. *Thecidæ*.—Corallum massive; a dense spurious cœnenchyma formed by the lateral union of the septa; tabulæ numerous.
2. *Favositidæ*.—Septa and corallites distinct; little or no true cœnenchyma.
3. *Seriatoporidæ*. — Corallum arborescent; sclerenchyma abundant and compact; tabulæ few.
4. *Milleporidæ*.—Corallum massive or foliaceous; septa not numerous; sclerenchyma tabular or cellular.

II. Perforata.—Septa well developed; no tabulæ; dissepiments rudimentary; sclerenchyma porous.

5. *Eupsammidæ*.—Corallum simple or composite; septa well developed and lamellar; columella spongiose.
6. *Poritidæ*.—Corallum composed of spongy, reticulated sclerenchyma. Septa never lamellar, but consisting wholly of a more or less definite series of trabeculæ; no tabulæ.
7. *Madreporidæ*.—Corallum usually composite; cœnenchyma abundant and spongy; thecæ porous, not distinct from the cœnenchyma; septa distinct, but slightly perforate.

III. Aporosa.—Septa well developed, completely lamellar, and primitively consisting of six elements; no tabulæ; sclerenchyma imperforate.

8. *Fungidæ*.—Corallum simple or compound; thecæ ill developed, and somewhat porous; no dissepiments or tabulæ; synapticulæ numerous.
9. *Astræidæ*.—Corallum simple or compound; no proper cœnenchyma; numerous dissepiments; no synapticulæ. Corallites well defined, and separated from one another by perfect walls.
10. *Oculinidæ*.—Corallum composite; cœnenchyma abundant and compact; dissepiments few in number. Walls of the corallites without perforations, not distinct from the cœnenchyma.
11. *Turbinolidæ*. — Corallum usually simple; no cœnenchyma; septa well developed; no dissepiments, nor synapticulæ.

IV. Tubulosa.—Septa indicated by mere striæ; thecæ pyriform; corallites sometimes connected by a creeping basal cœnenchyma.

12. *Auloporidæ*.—This being the only family in the *Tubulosa*, its characters are necessarily the same as those of the division itself.

B. Order Rugosa.—Characterised by the possession of a sclerodermic corallum, usually with septa and tabulæ combined, the former being in multiples of four. The corallites are always distinct, and are never united

together by a true cœnenchyma. The septa are usually incomplete, but are never porous, and never bear synapticulæ. The order is divided into the following four families:—

Family 1. *Stauridæ*.
Corallum simple or composite; septa incomplete, united by lamellar dissepiments; four large primary septa, forming a cross.

Family 2. *Cyathaxonidæ*.
Corallum simple; septa complete; no dissepiments or tabulæ; without four primary septa.

Family 3. *Cyathophyllidæ*.
Corallum simple or composite; septa incomplete; tabulæ generally present.

Family 4. *Cystiphyllidæ*.
Corallum simple, composed chiefly of a vesicular mass with but slight traces of septa.

Order III. Alcyonaria.—The Alcyonarian Zoophytes differ from the *Zoantharia* in the fact that *the polypes have eight pinnately fringed tentacles, the mesenteries also being some multiple of four*. The *Alcyonaria* thus differ from the *Zoantharia*, and agree with the *Rugosa* in the numerical proportion of their soft parts. The *Alcyonaria*, however, differ from the *Rugosa* in never possessing a sclerodermic coral divided by septa. When they have a sclerodermic corallum at all, it either consists simply of scattered spicules (as in *Alcyonium*), or, if thecal, consists of simple tubes which are not subdivided by vertical partitions or septa (as in the *Tubiporidæ*). We have, however, nothing to do with these forms, as they are unknown in a fossil condition. The only members of the *Alcyonaria* which have left any traces of their past existence, are those which possess a "sclerobasic" coral, in the form of a simple or branched internal axis, which may be calcareous or corneous, or partly the one and partly the other. Such forms are well represented at the present day by the Sea-pens (*Pennatulidæ*), the Sea-shrubs and Red Coral (*Gorgonidæ*), the Fan-corals (*Rhipidogorgia*), and the like. They are, however, of very small palæontological importance.

The genus *Protovirgularia* has been constituted for the reception of an obscure Silurian fossil, from its supposed affinity to the living Sea-rods (*Virgularia*). This problematical organism, however, is almost certainly not one of the *Alcyonaria*, and may, perhaps, belong to the *Hydrozoa*. With this exception, and the still more dubious examples of *Gorgonidæ* from the Silurian Rocks, no Alcyonarian Zoophyte has been detected in deposits older than the Chalk. One of the *Pennatulidæ* (viz., *Graphularia*) has been found in the London Clay (Lower Eocene); and the same formation has likewise yielded two species of *Gorgonidæ* (*Mopsea* and *Websteria*).

The genus *Corallium* (including the living Red Coral) has likewise been found in deposits of Miocene age.

CHAPTER X.

SUB-KINGDOM III.—ANNULOIDA.

ECHINODERMATA.

SUB-KINGDOM III.—ANNULOIDA.—*Animals in which the alimentary canal is completely shut off from the general cavity of the body. Nervous system distinct. A peculiar system of canals, usually communicating with the exterior and containing water derived from the outside, and termed the "water-vascular" or "aquiferous" system, is present in all. In none is the body of the adult composed of definite segments, or provided with "bilaterally disposed successive pairs of appendages."*

This sub-kingdom was proposed by Huxley, as a provisional arrangement, to include the two groups of the *Echinodermata* (Sea-urchins, Star-fishes, &c.) and the *Scolecida* (Tape-worms, Round-worms, Wheel-animalcules, &c.) Whether this arrangement be ultimately retained or not, matters not at all to the palæontologist, as no member of the *Scolecida* is known in the fossil condition. The palæontologist, therefore, has simply to deal with the *Echinodermata*, the complete distinctness of which, as a group, is beyond question.

CLASS ECHINODERMATA.

The class *Echinodermata* comprises the animals known commonly as Sea-urchins, Star-fishes, Brittle-stars, Sea-lilies, and Sea-cucumbers, and is distinguished by the fact that *the external envelope of the body* ("perisome") *has the power of secreting calcareous matter to a greater or less extent. The integument is, therefore, either composed of calcareous plates articulated together, or is coriaceous, and has granules or spicules of lime developed in it. The water-vascular system usually communicates with the exterior, and generally subserves locomotion. The adult animal exhibits more or less distinctly a "radial symmetry" or star-like arrangement of its parts, but the young animal is more or less bilaterally symmetrical.*

The *Echinodermata* are divided into the following seven orders :—

1. *Echinoidea.—Ex.* Heart-urchin (Spatangus).
2. *Asteroidea.—Ex.* Star-fish (Uraster).
3. *Ophiuroidea.—Ex.* Brittle-star (Ophiura).
4. *Crinoidea.—Ex.* Stone-lily (Encrinus).
5. *Cystoidea.—Ex.* Hemicosmites.
6. *Blastoidea.—Ex.* Pentremites.
7. *Holothuroidea.—Ex.* Trepang (Holothuria).

The above is not a true or natural arrangement of the orders of the *Echinodermata*, but it is convenient for many reasons to consider them in this sequence. As regards the general distribution of the class, the *Echinodermata* are represented more or less abundantly in all the great formations from the Upper Cambrian to the present day. The orders *Cystoidea* and *Blastoidea* are not only extinct, but are exclusively Palæozoic; in the *Crinoidea* we have an order which has passed its prime, and appears to be verging on extinction. On the other hand, the orders *Echinoidea*, *Asteroidea*, *Ophiuroidea*, and *Holothuroidea* appear to have attained their maximum of development at the present day. The *Asteroidea* and *Ophiuroidea* commence in the Silurian period. The *Echinoids* commence in the Upper Silurian, but reach no marked development till we enter upon Mesozoic deposits. Lastly, the *Holothurians*, as might be expected from the soft nature of their integuments, are hardly known as fossils, though they seem to have existed in the Mesozoic period.

Order I.—Echinoidea.

The members of this order—commonly known as Sea-urchins—are characterised by the possession of *a more or less globular, heart-shaped, discoidal or depressed body, encased in a "test" or shell, which is composed of numerous calcareous plates, immovably connected together. The intestine is convoluted, and there is a distinct anus. The mouth is usually armed with calcareous teeth, and is always situated on the inferior aspect of the body, but the position of the vent varies.*

As a matter of course, the palæontological student has to deal with nothing except the test of the Echinoids and its appendages, and these must be described in some detail. The "test" of the *Echinoidea* may be regarded as essentially composed of the so-called "corona" and of the "apical disc," though other less important elements are present as well. The "corona" is the main element of the test, and includes all the calcareous covering of the animal except the scattered plates round the mouth and anus and the "apical disc." The test is composed of numerous calcareous plates, firmly united

to one another by their edges, arranged in rows (fig. 57), and bearing different names according to their position and function. In one or two exceptional cases the plates are so thin

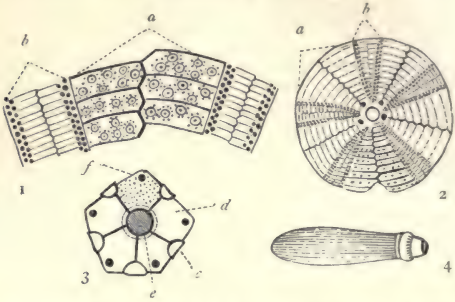


Fig. 57.—Morphology of Echinoidea. 1. Portion of the test of *Galerites hemisphericus* enlarged, showing an inter-ambulacral area (*a*), and an ambulacral area (*b*). 2. *Galerites hemisphericus* viewed from above. *a* Inter-ambulacra; *b* Ambulacra. 3. Genital and ocular disc of *Hemicidaris intermedia* enlarged. *c* Ocular plate; *d* Genital plate; *e* Anal aperture; *f* Madreporiform tubercle. 4. Spine of the same. (After Forbes.) The tubercles are mostly omitted on figs 2 and 3 for the sake of clearness.

and are so united together that the entire test becomes flexible and soft. As a rule, however, the corona forms an immovable case or box, within which the animal is contained; and its growth is carried on by means of additions made to the edge of each individual plate, by means of an organised membrane which passes between the sutures, or the lines where the plates come in contact with one another.

In all recent and most fossil Echinoids, the test is composed of twenty rows of calcareous plates, which are arranged in ten alternating zones or areas (fig. 58). Each zone, therefore, is composed of two rows of plates. In five of these zones (fig. 57, 1, and fig. 58) the plates are of large size, and are not perforated by any apertures. These zones are called the "inter-ambulacral areas." The remaining five zones alternate with the former, and are composed of very much smaller plates, which are perforated by minute apertures or pores. Through these apertures are emitted the little suctorial tubes of the water-vascular system—the so-called "ambulacral tubes" or "tube-feet"—by means of which the animal moves. Hence these zones of perforated plates are termed the "ambulacral areas" or "poriferous zones."

In one great group of the Echinoids, the ambulacral areas pass from the centre of the base of the shell to its summit (fig. 58), when they are said to be "perfect" (*ambulacra perfecta*) or "simple." In another great group the ambulacral

Fig. 58.—*Galerites albogalerus.* The first figure shows the under surtace with the mouth and anus. The middle figure is a side view: and the right-hand figure shows the upper surface, with the ambulacral areas converging to the apical disc. White Chalk.

areas are not thus continuous from pole to pole, but simply form a kind of rosette upon the upper surface of the shell (fig. 59). In these cases—as in the common Heart-urchins—

Fig. 59.—*Scutella subrotunda,* showing petaloid ambulacra. Miocene.

the ambulacral zones are said to be "circumscript" (*ambulacra circumscripta*) or "petaloid."

The most important external structures of the corona are the tubercles and spines. The tubercles are rounded elevations upon which the spines are carried (fig. 60). They vary much in their dimensions, and receive special names according to their size or position on the test. Ordinarily the tubercle consists of a rounded ball or hemisphere (the "mamelon") supported upon a conical process (the "boss") which arises from the plate. The ball of the tubercle may or may not be perforated for the insertion of a ligament which is attached to the articular surface of the spine. In many cases (as in fig. 60) the base of the tubercle is surrounded a round or oval smooth and excavated space which is termed the "areola."

The spines are movable appendages which are jointed

to the tubercles by a sort of "ball-and-socket" or "universal" joint. They are used defensively and in locomotion, and vary much in length and shape. Sometimes they are very minute; at other times they attain a length considerably exceeding the diameter of the test. Sometimes they are slender,

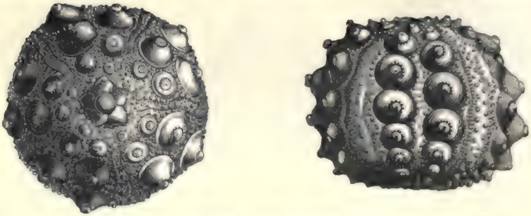


Fig. 60.—*Hemicidaris crenularis*, showing tubercles, the larger of which are perforated, and are surrounded by an areola. Oolite.

tapering, and truly spine-like; at other times they are thickened, ovate, or almost globular (fig. 61). The spine fits on the rounded head of the tubercle by a concave articular surface ("acetabulum"), and there may or may not be a pit at the bottom of this, for the attachment of the ligament before spoken of. Above the acetabulum or socket of the spine there is a prominent ridge or ring, more or less "milled," for the attachment of the muscular fibres which move the spine.

Fig. 61.—Spine of *Cidaris glandiferus*.

The "apical disc" or "genital disc" occupies the summit of the test, and is generally composed of ten plates (fig. 57, 3). Five of these plates are of comparatively large size, and are termed the "genital plates," each being perforated by the duct of an ovary or testis. Each genital plate occupies the summit of one of the interambulacral areas. One of the genital plates (the right antero-lateral plate) is larger than the others, and supports a spongy tubercle, perforated with many apertures, like the rose of a watering-pot, and termed the "madreporiform tubercle" (fig. 57). This structure protects the mouth of the canal by which water is admitted from the exterior to the water-vascular system. Wedged in between the genital plates, and occupying the summits of the ambulacral areas, are five smaller, heart-shaped, or pentagonal plates, each of which is perforated for the reception of an "ocellus" or eye, and which are therefore termed the "ocular plates."

An important division of the Echinoids is constituted by the position of the anal aperture. In one great group of Echinoids the mouth is situated in the centre of the base (fig. 62), and the vent is placed at the summit of the test, surrounded by the genital disc. These are the so-called "regular" Sea-urchins

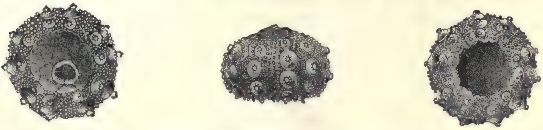


Fig. 62.—*Salenia personata*, a "regular" Echinoid. The left-hand figure represents the upper surface of the shell, and shows the anus surrounded by the apical disc. The right-hand figure shows the mouth in the centre of the base.

(*Echinoidea endocyclica*). They have a test which is almost always circular, or spheroidal, or, it may be, depressed; and the mouth is armed with a complicated masticatory apparatus. In the second great group the mouth is situated on the lower surface of the test, and is sometimes central, sometimes excentric in position. The anus varies in position, but is never placed on the summit of the test, opposite to the mouth. The anus, therefore, is not surrounded by the genital disc. Most commonly the anus is marginal, or is sub-marginal, coming to be placed in this last case on the lower surface of the test near the mouth (fig. 63). The Sea-urchins in which this state of

Fig. 63.—*Discoidea cylindrica*, an "irregular" Echinoid. The right-hand figure shows the summit of the shell, with the genital disc. The left-hand figure shows the base of the shell, on which are situated both the mouth and anus.

parts obtains are termed the "irregular" Echinoids (*Echinoidea exocyclica*). They are further distinguished by being mostly oblong, pentagonal, heart-shaped, or discoidal in form, by being mostly destitute of any masticatory apparatus, and by having only four perforated genital plates.

Another group must be constituted for the reception of the Sea-urchins of the Palæozoic Rocks, which differ materially from the Mesozoic, Kainozoic, and Recent Echinoids. Only

two genera are known in the Palæozoic series, viz., *Archæocidaris* and *Palæchinus*, but these differ from all the modern forms in the fact that the corona of the test was composed of *more than twenty rows of plates.* The test was divided into five ambulacral and five interambulacral areas, and the increase in the number of plates arises from the fact that each interambulacral area consists of three, five, or more rows of plates (fig. 64). From this peculiarity the Palæozoic urchins

Fig. 64.—*Archæocidaris ellipticus.* The left-hand figure shows a portion of an ambulacral area enlarged. The right-hand figure exhibits a single plate.

were placed in a separate sub-order by M'Coy, under the name of *Perischoechinidæ* (the *Tesselata* of Pomel). The five interambulacral areas are surmounted dorsally by the genital plates, which are five in number, and in *Palæchinus* are doubly perforated. The five ambulacral areas are "simple," or are continuous from pole to pole, being surmounted by the ocular plates. These are said by Baily to be triply perforated in *Palæchinus*, but they are said by De Koninck to be wanting. The test in both genera appears to be "regular."

As regards the distribution of the Echinoidea in time, the genera *Archæocidaris* and *Palæchinus* (the *Perischoechinidæ*) are exclusively Palæozoic, the former being confined to the Devonian, Carboniferous Limestone, and Permian, whilst the latter occurs both in the Carboniferous and in the Upper Silurian. The normal Echinoids abound in the Mesozoic series, especially in the Oolitic and Cretaceous Rocks, and are also well represented in the Tertiary Rocks. Their distribution will be shortly noticed under the head of each family.

The *Echinoidea* are divided into the following more important families, with their leading characters, distribution in time, and a few illustrative genera :—

1. *Ananchytidæ.*—Mouth excentric, in front; anus behind,

marginal, or supramarginal. Ambulacra composed of simple pores, not petaloidal. Apical disc of four perforated genital plates and five ocular plates. Spines minute. No masticatory apparatus. *Distrib.* Jurassic and Cretaceous. *Ill. Gen. Ananychytes.*

2. *Spatangidæ* (Heart-urchins). Test oval, oblong, or commonly heart-shaped, exhibiting distinct bilateral symmetry. Mouth excentric. Anus posterior and supramarginal. Ambulacra petaloid, the anterior one unpaired, usually lodged in a groove or "sulcus." Four genital pores. Mouth toothless. Spines minute and hair-like. *Distrib.* Cretaceous to Recent. *Ill. Gen. Spatangus, Micraster, Eupatagus, Amphidetus.*

3. *Collyritidæ* or *Dysasteridæ* (sometimes placed with the *Ananchytidæ*, sometimes in the following order of the *Echinoneidæ*). Test circular or oval. Mouth excentric; anus supramarginal. Ambulacra not petaloidal, meeting at two points on the upper surface, which are more or less apart. Four generative pores. Mouth toothless. *Distrib.* Oolitic and Cretaceous. *Ill. Gen. Collyrites* (*Dysaster*).

4. *Echinoneidæ.*—Test oval. Mouth nearly central; anus basal or marginal. Ambulacra not petaloidal, continuous from mouth to apical disc. Four generative pores. Mouth toothless. *Distrib.* Cretaceous to Recent. *Ill. Gen. Echinoneus, Pyrina.*

5. *Cassidulidæ.*—Mouth central, or nearly so; anus supramarginal or infra-marginal. Ambulacra more or less petaloidal, similar or dissimilar. Four generative pores. Apical disc sometimes excentric. Mouth toothless. *Distrib.* Oolitic to Recent. *Ill. Gen. Clypeus, Pygaulus, Pygurus.*

6. *Clypeasteridæ.*—Mouth central; anus marginal or inframarginal, posterior. Dorsal portions of the ambulacra petaloid. Five genital plates surrounding the madreporiform tubercle. Mouth toothed. *Distrib.* Cretaceous to Recent. *Ill. Gen. Clypeaster, Scutella* (fig. 59), *Echinocyamus.*

7. *Echinoconidæ.*—Mouth central; anus on the upper surface behind, or on the lower surface, sometimes mounting so high as to enter into the genital disc. Ambulacra simple, narrow. Apical disc with five genital plates. Spines small. Mouth toothed. *Distrib.* Oolitic and Cretaceous. *Ill. Gen. Galerites* (fig. 58), *Echinoconus, Pygaster, Holectypus.*

8. *Cidaridæ.*—Test regular, spheroidal. Mouth central; anus opposite the mouth, surrounded by the genital disc. Ambulacra narrow, straight, or flexuous. Spines large, mostly club-shaped. Mouth toothed. *Distrib.* Triassic to Recent. *Ill. Gen. Cidaris, Temnocidaris.*

9. *Echinidæ.*—Test regular, spheroidal. Mouth central; anus opposite the mouth, surrounded by the genital disc. Ambulacra wide or narrow, usually wide centrally, diminishing towards the mouth and anus. Mouth toothed. Spines varied in length and shape.

Section *a. Salenidæ.*—Apical disk of more than ten plates, large, with the anus placed excentrically in it. *Distrib.* Oolitic to Tertiary. *Ill. Gen. Salenia* (fig. 62), *Acrosalenia.*

Section *b. Diademadæ.*—Ambulacral areas with two or four rows of large tubercles. *Distrib.* Jurassic to Recent. *Ill. Gen. Diadema, Astropyga.*

Section *c. Hemicidaridæ.*—Interambulacra with two rows of large tubercles. *Distrib.* Triassic to Cretaceous. *Ill. Gen. Hemicidaris* (fig. 60).

Section *d. Echinidæ Proper.*—Ambulacral and interambulacral areas with large tubercles. *Distrib.* Jurassic to Recent. *Ill. Gen. Echinus, Temnopleurus.*

10. *Perischoechinidæ.*—Test regular. Mouth central, inferior; anus opposite to the mouth, surrounded by the genital disc. Ambulacra simple, perfect. Corona composed of more than twenty rows of plates, each interambulacral area consisting of from three to six rows. *Distrib.* Upper Silurian to Carboniferous. *Ill. Gen. Archæocidaris* and *Palæchinus.*

CHAPTER XI.

ASTEROIDEA AND OPHIUROIDEA.

ORDER II. ASTEROIDEA.

THE order *Asteroidea* or *Stellerida* comprises the ordinary "star-fishes," and is defined by the fact that *the body* (fig. 65) *is star-shaped or pentagonal, and consists of a central "disc," surrounded by five or more lobes or "arms." The arms are truly prolongations of the body, are hollow, and contain prolongations of the stomach in their interior. The arms are, further, grooved on their under surface for the reception of the ambulacral or water-vascular vessels. From these grooves the tube-feet are protruded in two or four rows. The integument (perisome) is leathery, but is more or less calcified by the development in it of plates, granules, and spines of carbonate of lime. The mouth is*

inferior in position, and is toothless. An anus is usually present, but may be absent.

The two most striking features which distinguish the Star-fishes from the Sea-urchins are the star-like figure of the former, and the fact that the body is not enclosed in an immovable calcareous box or "test," as it is in the latter. The integument of the *Asteroidea* is, however, so richly provided with calcareous matter, that though more or less soft and flexible during life, it is quite capable of being preserved in a fossil condition. It is, of course, wholly with the calcareous secretions of the animal that the palæontologist has to deal; and we may, therefore, dispense with any further account of the soft parts, beyond what is contained in the above definition.

In their form the Star-fishes differ considerably, though in most the figure is markedly stellate. The animal consists of a central body or "disc," which gives off radiating processes or "arms," but the size of the disc is very different in different species, and the arms vary greatly in length and in number. In many living and extinct forms the "disc" is inconspicuous, and appears to be formed simply by the junction of the bases of the arms, which in this case are normally five in number. The living *Urasters* and *Cribellæ*, and the extinct *Palæasters* (fig. 65), may be taken as examples of this state of parts. In other forms, as in the Sun-stars (*Solaster*) and the extinct *Lepidasters* and *Plumasters*, the disc is very broad, exceeding or equalling the length of the arms in its diameter; whilst the rays vary in number, from eight or ten up to thirty or more. In the Cushion-stars (*Goniaster* and *Goniodiscus*), again, the body is pentagonal, disc-shaped, and flattened on the two sides, and the arms can only be recognised by the ambulacral grooves on the lower surface (fig. 66).

Fig. 65.—*Palæaster Niagarensis.* Hall. Lower Silurian.

On the upper surface of the body, placed nearly in the centre of the disc, is the aperture of the anus, when this is present; but the genera *Astropecten*, *Ctenodiscus*, and *Luidia* are destitute of a vent. Also on the upper surface is the "madreporiform tubercle," in the form of a spongy or striated disc placed at the angle of junction of two rays. It has the same function as in the Echinoids, serving to protect the

entrance to the water-vascular system. Ordinarily there is a single madreporiform tubercle, but in some genera there are two, three, or more tubercles; and there seems in some cases to be a correspondence between the number of the arms and the number of madreporic plates.

Placed in the centre of the lower surface is the mouth, at the angles of which are the so-called "oral plates" (fig. 66). Radiating from the mouth are a series of furrows, varying in number with the arms, and termed the "ambulacral grooves." Each ambulacral groove is continued along the lower surface of one of the arms, tapering gradually towards the extremity of the latter. The floor of each groove is constituted by a double row of minute calcareous pieces — the "ambulacral ossicles"—which are movably articulated to one another at their inner ends. At the bottom of each groove is lodged one of the radiating canals of the water-vascular system or ambulacral system, from which are given off the rows of suctorial feet, or "tube feet." It follows from this that the radiating vessels of the ambulacral system are *outside* the chain of ambulacral ossicles, so that these latter are to be regarded as an *internal* skeleton, and they do not correspond with any part of the skeleton of Echinoids* — at least they do not correspond with the perforated ambulacral plates of the Sea-urchins. The ambulacral ossicles, however, of the Star-fishes are of such a form that by their apposition an aperture or pore is formed between each pair. By means of these pores (fig. 66, *a*) the tube-feet communicate with a series of little bladders placed *above* the chain of ossicles. These perforations, however, do not correspond with the perforated plates of the Echinoid test, and the tube-feet of the Star-fishes pass through no "poriferous" plates on their way to the exterior.

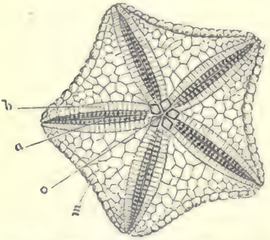


Fig. 66.—Diagram of a Star-fish (*Goniaster*), showing the under surface, with the mouth and ambulacral grooves. *a*, Ambulacral ossicles, with the ambulacral pores between them. *b*, Adambulacral plates, bounding the ambulacral grooves; *m*, Marginal plates (wanting in many species); *o*, Oral plates, placed at the angles of the mouth.

This may be rendered more intelligible by examining a

* The structures in the *Echinus*, which are truly homologous with the ambulacral ossicles of the *Asteroidea* and *Ophiuroidea*, are the so-called "auriculæ."

section of the arm of a Star-fish from which the soft parts have been removed (fig. 67). In such a section the ambulacral ossicles (*a*, *a*) are seen in the centre of the lower surface, united along the middle line by their inner extremities. They are so placed as to form a kind of elongated pent-house, and immediately beneath the line where the ossicles of one side are articulated with those of the other side is placed the ambulacral vessel (*b*). Superficial to this, again, is a nerve-cord; so that the whole chain of ambulacral ossicles is placed in the midst of the soft parts of the animal, and is thus clearly an internal skeleton. At their outer extremities the ambulacral ossicles are articulated by the intervention of the "adambulacral plates" (fig. 66, *b*), with plates belonging to the external or integumentary skeleton, to be immediately described. As before said, the shape of the ambulacral ossicles is such that a

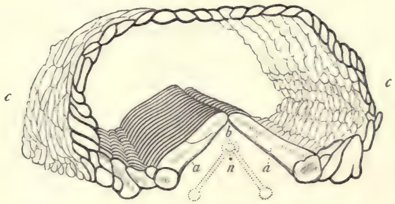


Fig. 67.—Section of the ray of *Uraster rubens*. *a*, *a* Ambulacral ossicles; *b* Position of the ambulacral vessel; *c*, *c* Plates of the external skeleton; *n* Nerve-cord. The dotted lines show the tube-feet proceeding from the ambulacral vessel.

pore is formed by the apposition of each pair; and by these apertures each tube-foot communicates with a vesicle placed internal to the chain of ossicles. It will be seen, however, that the tube-feet (indicated by the dotted lines in the figure) do not pass through these apertures, or through any other pores of the skeleton, on their way to the surface. The "poriferous zones" of the Sea-urchins are part of the external skeleton, and are not represented in the Star-fishes. On the other hand, the integumentary skeleton in the Star-fishes *is absent* along the ambulacral areas, or along the areas occupied by the ambulacral grooves.

Leaving the ambulacral ossicles or internal skeleton of the *Asteroidea*, we come now to the integumentary skeleton. This consists of a vast number of small calcareous pieces, or "ossicles," united together so as to form a species of chain-armour.

The ossicles are united with one another in a reticulated manner, and the interspaces between them are filled by the coriaceous integument. In some genera there is a single or double row of large plates round the borders of the disc and arms (fig. 66, *m*). These are termed the "marginal plates." The integument in the Star-fishes is also furnished with spines, tubercles, and granules of calcareous matter. The spines vary in their development and in their position in different Star-fishes; but there is commonly a row of spines along each side of each of the ambulacral grooves. In some genera (as in *Solaster*, *Luidia*, *Ctenodiscus*, &c.) there are spines the summits of which carry bunches or tufts of minute calcareous processes. These are termed "paxillæ." Lastly, in *Asteroidea*, as in *Echinoidea*, there are the modified pincer-like spines which are known by the name of "pedicellariæ."

As regards their geological distribution, the *Asteroidea* have a long vertical range, extending from the Lower Silurian Rocks to the present day. In Silurian seas Star-fishes abounded, and the Upper Silurian Rocks especially contain their remains in what may be considered as plenty. The leading Silurian genera are *Palæaster*, *Stenaster*, *Palasterina*, *Palæocoma* (Salter), *Palæodiscus*, and *Petraster*. Some of the more familiar Silurian forms are figured below (fig. 68). The next period in which

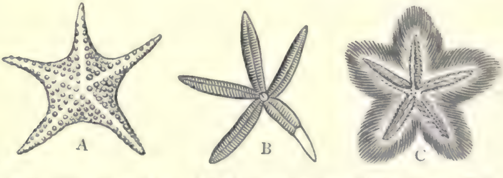


Fig. 68.—Silurian Star-fishes. A, *Palasterina primæva*, Upper Silurian; B, *Palæaster Ruthveni*, Upper Silurian; C, *Palæocoma Colvini*, Upper Silurian. (After Salter.)

Star-fishes abound is the Oolitic or Jurassic (Mesozoic), the more important genera being *Uraster*, *Luidia*, *Astropecten*, and *Goniaster*. All the Oolitic species are extinct, but the genera have mostly survived to the present day. In the Cretaceous period, also, many Star-fishes occur, the genera *Oreaster*, *Goniodiscus*, and *Stellaster* being the most noticeable. In the Tertiary Rocks remains of Star-fishes are not abundant, but the genera *Goniaster* and *Astropecten* are represented in the London Clay (Eocene).

No thoroughly satisfactory classification of the *Asteroidea* has been as yet proposed, but the following are the names of the more important fossil genera, with their range in time:—

Stenaster.	Lower Silurian.
Petraster.	————
Palæaster.	Lower Silurian to Carboniferous.
Palasterina.	Upper Silurian.
Palæocoma (Salter).	————
Palæodiscus.	————
Lepidaster.	————
Pleuraster.	Trias.
Uraster.	Jurassic to Recent.
Solaster.	————
Astrogonium.	————
Goniaster.	————
Astropecten.	————
Luidia.	————
Arthraster.	Cretaceous.
Oreaster.	————
Stellaster.	Cretaceous to Recent.
Goniodiscus.	————

Order III.—Ophiuroidea.

The *Ophiuroidea* are often grouped with the *Asteroidea*, and the living members of the order are known commonly as Brittle-stars and Sand-stars. They are distinguished from the true Star-fishes by the fact that *the "disc" contains all the internal organs of the animal; the "arms" are not grooved inferiorly for the emission of ambulacral tube-feet; and the mouth is provided with a masticatory apparatus.* The *Ophiuroids* are very conspicuously star-shaped, and consist of a central "disc" and a series of radiating "arms" (fig. 69). The "disc" is truly disc-shaped, and is covered with granules, spines, or scales. From the disc proceed the arms, in the form of long and slender processes, which may be simple or branched, but which differ from the arms of Star-fishes in not containing any prolongations from the stomach, and in never having their under surfaces furrowed by ambulacral grooves. The arms, in fact, are special processes superadded for the purposes of prehension and locomotion, and rendered necessary by the fact that the ambulacral system takes no part in the function of locomotion, as it does in the Star-fishes. A madreporiform tubercle, however, is present, and is placed on the inferior surface of the body, being commonly concealed by one of the plates surrounding the mouth. The mouth, as in the Star-fishes, is placed in the centre of the lower surface of the disc;

but the stomach terminates blindly; and there is, therefore, no anal aperture.

Each arm is furnished with an internal and an external skeleton. The internal skeleton consists, as in the star-fishes, of a chain of "ambulacral ossicles," placed along the centre of the arm. The ossicles are, however, now amalgamated in pairs, each coalescing with its fellow on the opposite side; so that in place of a double row of movably articulated ossicles, we have a single row of bilaterally symmetrical pieces.

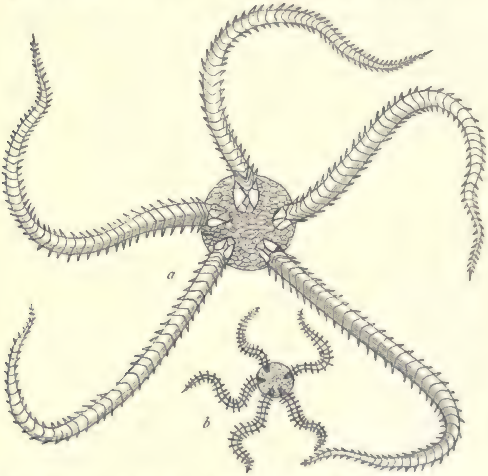


Fig. 69.—Recent Ophiuroids. *a Ophiura texturata*, the common Sand-star; *b Ophiocoma neglecta*, the grey Brittle-star (after Forbes).

The external skeleton of the arms is composed of four rows of plates, one on the dorsal surface, one on the ventral, and one on each lateral surface. The lateral plates generally carry more less developed spines. In the extinct genus *Protaster* it is said that the plates of the ventral row are double; and *Ptilonaster* is stated to possess four ventral rows of plates. The disc, as before said, has a well-developed external skeleton of scales, granules, and spines; but there are never any of those modified spines which are known as "pedicellariæ," and which occur in the Asteroids and Echinoids.

As regards their distribution in time, the *Ophiuroidea* are represented for the first time in the Upper Silurian Rocks by the genus *Protaster* (fig. 70), unless *Tæniaster* be rightly re-

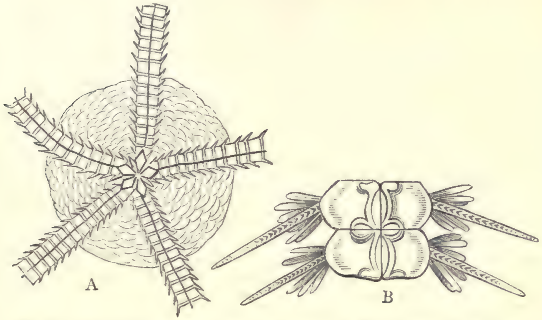


Fig. 70.—*Protaster Sedgwickii.* Upper Silurian. A, Disc and bases of the arms, magnified. B, Portion of an arm greatly enlarged.

ferred here, in which case the order begins in the Lower Silurian. No other Palæozoic genera have been satisfactorily made out. In the Muschelkalk, the middle member of the Trias, we have a well-marked species, the *Aspidura loricata* of Goldfuss (fig. 71). In the Oolitic, Cretaceous, and Tertiary

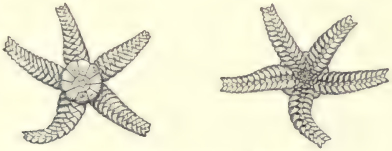


Fig. 71.—*Aspidura loricata.* Muschelkalk.

Rocks, Ophiuroids are by no means uncommon, and they belong for the most part to genera which exist at the present day. Great uncertainty prevails as to the generic characters of these animals; but the Mesozoic forms are for the most part generally referred to the genera *Ophiolepis*, *Ophioderma*, *Ophiocoma*, *Amphiura*, and *Acroura*.

CHAPTER XII.

CRINOIDEA, CYSTOIDEA, AND BLASTOIDEA.

ORDER IV.—CRINOIDEA.

THE *Crinoids* or Sea-lilies are *Echinodermata* in which *the body is fixed, during the whole or a portion of the existence of the animal, to the sea-bottom by means of a longer or shorter jointed or flexible stalk. The body is provided with solid arms which are primarily five to ten in number, are independent of the visceral cavity, and are grooved on their upper surface. The arms are furnished with lateral processes or "pinnulæ," and the reproductive organs are lodged beneath the integument on the ventral surface of these, and are not placed in the body-cavity.*

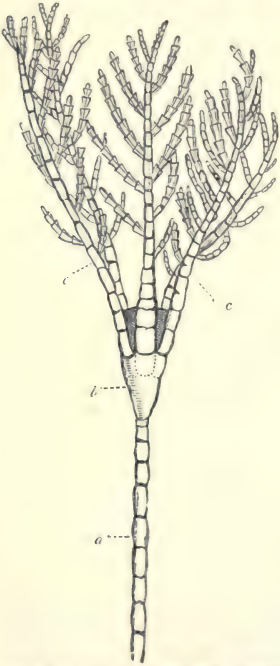


Fig. 72.—Crinoidea: *Rhizocrinus Lofotensis*, a living Crinoid (after Wyville Thomson), four times the natural size. *a* Stem; *b* Calyx; *c c* Arms.

If we take such a living Crinoid as *Rhizocrinus* (fig. 72), we shall be able to arrive at a comprehension of the leading characters of this order. *Rhizocrinus* is one of those Crinoids which is permanently rooted to some foreign object by the base of a stalk which is composed of a number of calcareous pieces or articulations. In some cases (as in *Apiocrinus*, fig. 81), the base of the stem or "column" is considerably expanded. In other cases the column is simply "rooted by a whorl of terminal cirri in soft mud" (Wyville Thomson). The joints of the column are movably articulated to one another, the joint-

surfaces often having a very elaborate structure, so that the entire stem possesses in the living state a greater or less amount of flexibility. Each joint is perforated centrally by a canal, which is, very inappropriately, termed the "alimentary canal," but which in truth has nothing to do with the digestive system of the animal. At the summit of the stem is placed the body, which is termed the "calyx," and which is usually more or less cup-shaped, pyriform, bursiform, or discoidal. The calyx exhibits two surfaces, a dorsal and a ventral, of which the dorsal is composed of calcareous plates articulated by their margins, whilst the former is composed of a more or less leathery integument strengthened by the deposition in it of numerous small plates of carbonate of lime. The ventral surface exhibits the aperture of the mouth, which may be sub-central or may be very excentric, and which in many extinct forms is wholly concealed from view. The ventral surface also exhibits the aperture of the anus, which is usually placed ex-centrically in one of the spaces between the arms, and which is generally, if not universally, carried at the end of a longer or shorter tubular eminence or process, which is called the "proboscis." Owing to the animal being supported on a stalk, it is evident that the "ventral" surface is turned upwards, and the "dorsal" surface downwards. The column springs from the centre of the dorsal surface; and a stalked Crinoid may, therefore, be compared to a Star-fish turned upside down, with its lower or ambulacral surface superior, and its dorsal surface looking downwards. The calyx contains the digestive canal and the central portions of the nervous and water-vascular (ambulacral) systems; but it does not contain the reproductive organs, as is the case with the visceral cavity of the other Echinoderms.

From the margins of the calyx, where the dorsal and ventral surfaces join one another, arises a series of longer or shorter flexible processes, which are composed of a great number of small calcareous articulations, and which are termed the "arms" (fig. 73). The arms are usually primarily five in number, but they generally divide almost immediately into two branches, each of which may again subdivide; the branches thus produced perhaps again dividing, until a crown of delicate graceful filaments is formed. The arms carry smaller lateral branches or "pinnulæ" on both sides; and they are not hollow like the arms of the Star-fishes, nor do they contain any prolongations of the stomach. The upper surface of the arms and pinnulæ is covered with a soft membrane, and below this are placed the reproductive organs. The generative organs are, there-

fore, not placed within the calyx, and it follows of necessity

that there is no generative opening or "ovarian aperture" in the walls of the calyx. The ventral surfaces of the arms and pinnulæ are furnished with grooves, which in the living species are seen to be covered with vibratile cilia. The brachial grooves coalesce till they constitute five primary grooves, which are continued from the bases of the arms to the mouth. The action of the cilia gives rise to a constant current of sea-water, bearing organic matter in solution; and this current proceeds from the brachial grooves to the mouth. In this way the animal obtains its food. As the bases of the arms are separated from the mouth by an intervening space, it follows that the brachial grooves are

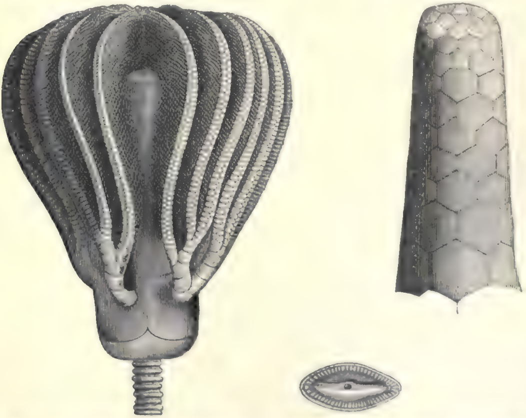


Fig. 73.—*Platycrinus tricontadactylus.* Carboniferous. The left-hand figure shows the calyx, arms, and upper part of the stem, and the figure next this shows the surface of one of the joints of the column. The right-hand figure shows the proboscis; and above is a magnified figure of part of one arm with its pinnulæ.

continued over the ventral surface of the calyx, till they reach the oral opening.

There is no doubt that it is by the above arrangement that the living Crinoids obtain their food, and the mechanism seems to have been essentially the same in many extinct species. In the Palæozoic Crinoids, however, there seems to have been a modification of this arrangement. In these forms, as in *Actinocrinus* (fig. 75), the arms have much the structure of those of the recent Crinoids, and are deeply grooved on their ventral surfaces. The ventral surface of the calyx, however, exhibits no central aperture, but only a proboscidiform tube, which arises from one of the inter-radial spaces (*i.e.*, one of the intervals between two of the arms). This tube is often of great length, and a good deal of controversy has taken place as to its nature. Without entering into the conflicting views upon this subject, it may be stated that the preponderance of authority is in favour of the view that this "proboscis" is an anal tube, having the vent at

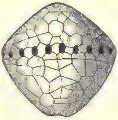


Fig. 74.—Calyx of *Actinocrinus rotundus.*

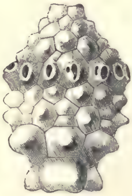


Fig. 75.—Calyx of *Actinocrinus Konincki.*

Fig. 76. — Calyx of *A. Verneuillanus.* The arms are wanting, and the apertures at their bases are seen.

its extremity. Good observers, however, regard it as discharging the functions of both the mouth and the anus. Be this as it may, the grooves on the ventral surfaces of the arms are certainly not continued over the ventral surface of the calyx, but, on the contrary, stop short at the bases of the arms. Their further course was long a mystery; but it is now known that they are continued below the ventral surface of the calyx as a series of covered passages or tunnels, the external apertures of which are placed at the points where the arms spring from the disc (see figs. 74-76). These covered channels are either simply roofed over by the calcareous integument of the calyx, or are rarely excavated in its walls; and they converge to a central point in the middle of the ventral surface of the disc. Here, it is believed, is placed the mouth, concealed by the calcareous plates of the perisome. From the known function of the brachial grooves in the living Crinoids, this view would

seem to be the most probable one; but, as before remarked, good authorities regard the excentric "proboscis" as the mouth.

In another group of Crinoids, represented by the living Feather-stars (*Comatula*) and the extinct *Saccosoma* (fig. 77),

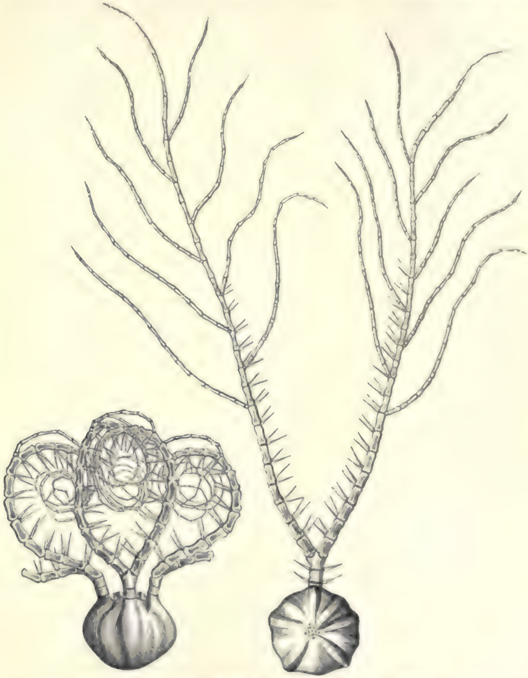


Fig. 77.—*Saccosoma pectinata*, a free Crinoid. Jurassic.

the animal is only *stalked* when young, and in its adult condition leads a free life. The young form in the members of this group is supported upon a jointed calcareous column, by which it is fixed to some foreign object; and at this stage it in no respect differs from the ordinary stalked Crinoids. At a

certain period of its existence, however, the calyx drops off its column, and becomes a locomotive animal. It now has a near resemblance to one of the Brittle-stars (*Ophiuroidea*); but is distinguished, not only by its developmental history, but by the possession of lateral pinnæ to the arms, and in having the reproductive organs situated external to the body proper. In the Feather-stars (*Comatula* or *Antedon*) the dorsal surface of the disc, at the point where the column was originally inserted, carries a series of jointed filaments or "cirri," by which the animal can moor itself to any foreign object. These may be regarded as homologous with the "side-arms" of the column of certain Crinoids. When the animal is thus temporarily moored by its dorsal cirri, it is placed in the ordinary position held by the Crinoids — namely, with the mouth and ventral surface of the disc looking upwards. When creeping about, on the other hand, by means of the long and flexible arms, the animal occupies the position held by the Star-fishes and Ophiuroids—namely, with the mouth and ventral surface of the disc directed downwards, or towards the ground.

Having now given a general account of the structure of the Crinoids, it remains to consider some of their parts in greater detail. In the first place, as regards the "column," we find that the stem of attachment is composed of a great number of separate plates or "articulations" placed one above the other, and so jointed to one another that whilst the amount of movement between any two pieces must be very limited, the entire column acquires more or less flexibility. The column is perforated by a round or five-sided canal which pierces every joint, and runs along the entire length of the stem. In the Palæozoic Crinoids, with few exceptions, the column was round; but in *Platycrinus* it is oval or elliptical (fig. 73). In the genera *Pentacrinus* (fig. 78) and *Extracrinus* the column is pentagonal in outline; but much less markedly so in the former than in the latter genus. The joints articulate with one another by surfaces or facets which are differently marked in different cases. In the Palæozoic forms, as in *Platycrinus* (fig. 73), the articulating facets are marked by more or less numerous striæ which radiate from near the centre of the joint. In most of the Mesozoic genera, on the other hand, as in *Pentacrinus* (fig. 78), the articulating facets are united by crenated ridges arranged in a pentapetalous figure. In many cases, as in *Extracrinus* and *Pentacrinus*, the column is furnished with more or less numerous "auxiliary" arms, or "side-arms," the function of which is not altogether clear.

The dorsal surface of the cup or "calyx" is composed of a number of calcareous plates accurately fitted together. The number and arrangement of these vary much in different

Fig. 78.—*Pentacrinus fasciculosus*, showing the form of the column, and one of the facets of a joint. The central figure shows the arms, and the summit of the column with side-arms.

genera, and it will be sufficient to indicate here their general disposition. Reposing directly upon the summit of the column

is a series of plates which are termed "basal" from their position, and which constitute the "pelvis" of Miller. The "basals" may be five, four, or sometimes three in number, and they form the lowest portion of the cup. In some cases the "basals" are succeeded by a second row or cycle of plates, which should properly be regarded, with Professor Beyrich, as a second series of basals, but which are sometimes regarded as something special, and are termed the "parabasals" or "sub-radials." The basals (fig. 79, *b*) are succeeded by a

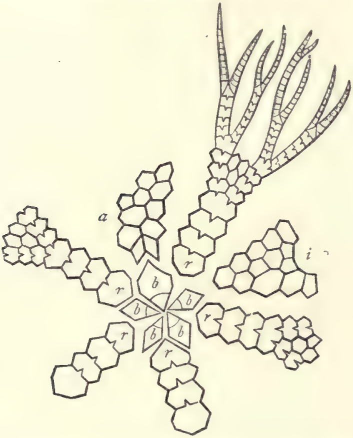


Fig. 79.—Diagram to show the structure of the calyx in the fossil Crinoids; *b* Basals; *r* Radials; *i* Inter-radials; *a* Anal plates. Calyx of *Forbesiocrinus*. (After Pictet.)

series of two or three rows of plates, which are directly superimposed upon one another, and which form the foundations of the arms (*r*, *r*). These are termed the "radials" (the "costæ" of Miller), and are termed "primary," "secondary," and "tertiary," according to their distance from the basals. The last radial plates, or those furthest from the column (sometimes called the "axillary radials"), give origin to the arms. The radial plates are arranged in a series of vertical columns, which extend from the summit of the basals to the bases of the arms. Between the different columns of radial plates, however, are intercalated certain other smaller plates, which

alternate with one another, and which are termed "interradials" (*i*). Lastly, one of the interradial spaces, corresponding with the anus, is usually much wider than the others, and is furnished with an additional series of plates, which are called the "anal plates" (*a*).

As regards their general distribution in time, the *Crinoidea* present us with an excellent example of a group which early attained its maximum of development, and which has now dwindled down to some half-dozen surviving species. With one or two doubtful exceptions, the Crinoids appear, so far as yet known, to have commenced their existence in the Lower Silurian period, and they are represented by numerous and very varied forms in the seas of the Upper Silurian period. Amongst the commoner Silurian genera may be mentioned *Crotalocrinus*, *Glyptocrinus*, *Ichthyocrinus*, *Periechocrinus*, *Rhodocrinus*, *Poteriocrinus*, and *Taxocrinus*. In the Devonian Rocks, also, Crinoids are plentiful, and the genera *Cupressocrinus*, *Haplocrinus*, and *Melocrinus*, may be mentioned as peculiar to this period. It is in the earlier portion, however, of the Carboniferous period that the Crinoids attain their highest development. The Carboniferous Limestone is in many places, over wide areas, and for a thickness of many yards, almost entirely made up of the debris of Crinoids; and in many places it is so charged with the remains of these organisms as to deserve and acquire the name of "crinoidal limestone" or "entrochal marble." Amongst the commoner Carboniferous genera may be mentioned *Cyathocrinus*, *Actinocrinus* (fig. 74), *Platycrinus* (fig. 73), *Poteriocrinus*, and *Taxocrinus*. It is in the Palæozoic period, then, that the Crinoids attain their maximum, both numerically and as regards the number of genera and species. Taken as a whole, the Palæozoic Crinoids are distinguished by the characters already mentioned; namely, by having the brachial grooves conveyed to the mouth in concealed channels or tunnels, in having mostly a rounded column, and in the fact that the articular facets of the column-joints usually are marked by numerous simple radiating striæ. As a rule, also, the Palæocrinoids have a calyx, in which the dorsal surface has a preponderating development as compared with the ventral surface.

Coming to Mesozoic times, Crinoids are still abundant, though certainly reduced in numbers as compared with their development in the Palæozoic period. Taken as a whole, the Mesozoic Crinoids are characterised by having the brachial grooves continued over the ventral surface of the disc, and by having the ventral portion of the calyx more extensively de-

veloped than the dorsal; whilst the articular surfaces of the column-joints are usually morticed to one another by means of crenated ridges which have a flower-like arrangement. Neither of these latter characters, however, is constant. In the Mesozoic Rocks, also, appear for the first time remains of the *free* Crinoids allied to the living *Comatulæ*. The genus *Saccosoma* (fig. 77) is exclusively Oolitic, and appears to form in some respects a connecting link between the true Crinoids and the *Ophiuroidea*. In the Chalk the genus *Comatula* seems to be represented; and the Cretaceous genus *Marsupites* (the "Tortoise Encrinite") presents us with a form which is intermediate between the fixed Crinoids and the forms which lead a free existence when adult.

Of the stalked Crinoids of the Mesozoic period, the genera *Encrinus*, *Pentacrinus*, *Extracrinus*, and *Apiocrinus* are especially noticeable. In the genus *Encrinus* (fig. 80) the arms are composed of a double series of alternating pieces, and carry pinnules on their inner surfaces. The joints of the column are perforated by a small round "alimentary canal." The best-known species is the famous Lily-encrinite (*E. liliiformis*, fig. 80), which is characteristic of the Muschelkalk, the middle member of the Trias.

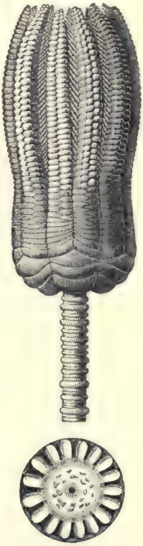


Fig. 80.—*Encrinus liliiformis.* Muschelkalk.

In the genus *Pentacrinus* and the nearly allied *Extracrinus*, the calyx is short and composed of few plates (five basals and five radials). The column is pentagonal, with whorls of side-arms, and the articulating surfaces of the joints are marked with pentapetalous ridges. The arms are long, slender, and branched. Amongst the best-known species are the *Pentacrinus fasciculosus* of the Lias, and other nearly allied forms of the same formation.

In the *Apiocrinidæ* or "Pear-Encrinites" (fig. 81), the animal was fixed to some foreign object by a dilated base, and the column was long and composed of numerous joints. The articulating surfaces of the column-joints are marked with simple ridges, and the stem is rounded and not pentagonal. The last joints of the column gradually increase in diameter, until they attain a size equal to the breadth of the

calyx. Upon the last of these developed column-joints rest the basal plates of the calyx proper, and upon the margins of the calyx is inserted a circle of bifid and pinnate arms. Although the calyx itself is of large size, the internal cavity or visceral chamber, in which the soft parts of the animal were contained, is comparatively very small. The best-known species of *Apiocrinus* are the *A. rotundus* of the Great Oolite and the *A. Roissyanus* (fig. 81) of the Coral Rag.

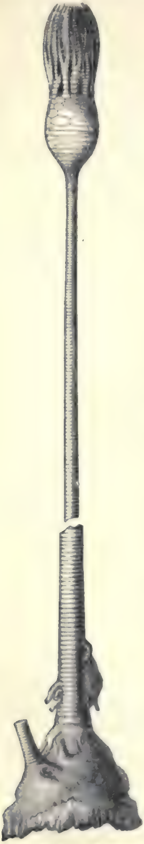


Fig. 81. — *Apiocrinus Roissyanus.* Middle Oolite (Jurassic).

In the Cretaceous period the *Apiocrinidæ* are represented by the genus *Bourgueticrinus*, and the living genus *Rhizocrinus* (fig. 72) would appear also to be a representative of this family. The free Crinoids are pretty well represented also in the Cretaceous period, the White Chalk having yielded the discs of *Comatulæ*, along with the singular " Tortoise-encrinite " (*Marsupites*), which would seem to connect the stalked Crinoids with the free forms.

In the Tertiary period the Crinoids are reduced, so far as is certainly known, to the single genus *Pentacrinus*, which is represented at the present day by the living *Pentacrinus Caput-Medusæ* of the Antilles. The best-known species is the *P. subbasaltiformis* of the Eocene.

A good classification of the Crinoids is still a desideratum. Commonly they have been divided into two groups termed respectively *Articulata* and *Tesselata*, according as the radial plates of the calyx are freely articulated to one another, or are immovably joined together without articulation. This arrangement is a far from satisfactory one ; but if accepted, we should have all the Mesozoic and Kainozoic Crinoids (except *Marsupites*) in the division of the *Crinoidea articulata*. On the other hand, the division of the *Crinoidea tesselata* would correspond with the Palæo-Crinoids, comprising all the species known from the Palæozoic formations.

The division of the Crinoidea into stalked and free forms is in many respects inapplicable as a basis of zoological classification. There can, however, be no doubt but that the free Crinoids are structurally an advance upon the fixed forms. It is, therefore, of interest to note that the stalked Crinoids had attained their maximum in the Palæozoic Rocks, and had even commenced to decline before the free Crinoids first made their appearance in the Mesozoic Series.

Order V.—Cystoidea.

The *Cystoidea* are *Echinodermata* in which *the body was enclosed in a series of calcareous plates accurately articulated by their edges, and was fixed to the sea-bottom by a longer or shorter flexible jointed stalk. There were rarely true arms, and if present, these structures are much less developed than in the true Crinoids.*

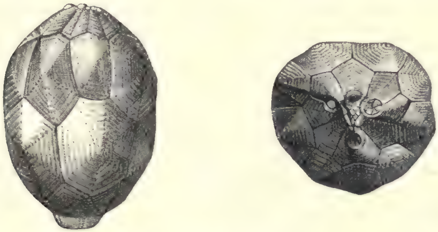


Fig. 82.—*Hemicosmites pyriformis*, one of the Cystideans. The right-hand figure shows the upper surface of the calyx.

In general form the Cystideans are globular, oval, pear-shaped, conical, or sub-cylindrical, and they resemble the Crinoids in consisting of a stem or "column" and a body or "calyx." The column is composed of a succession of calcareous joints, and in no respect differs from the column of the Crinoids. In *Lepadocrinus* (fig. 83, D), however, it is doubtful if the column was affixed to any foreign body, for its lower extremity is composed of a single, long, spindle-shaped piece. The stalk also is asserted to be absent altogether in *Sphæronites pomum* and in the genus *Agelacrinites.* The calyx consists of a number of polygonal calcareous plates accurately fitted together, and enclosing all the viscera of the animal. Sometimes the plates are indefinite in number and arrangement; but in other cases the number of plates is limited, and they are arranged according to a definite plan. In other cases

the number and arrangement of the plates may be definite on one side of the calyx and indefinite on the other.

As regards the structure of the arms of the Cystideans, there is a good deal of diversity. In some forms there were no true arms, comparable with the arms of the Crinoids; but there were small jointed processes, which were attached to the calyx, and which represent the "pinnulæ" or lateral branches of the arms of the Crinoids. In some cases, grooves—corresponding with the brachial grooves of the Crinoids—are seen to extend from the point of attachment of each pinnula

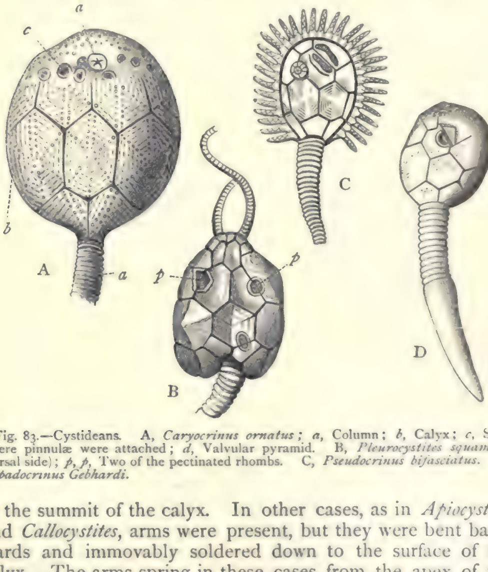


Fig. 83.—Cystideans. A, *Caryocrinus ornatus*; *a*, Column; *b*, Calyx; *c*, Scars where pinnulæ were attached; *d*, Valvular pyramid. B, *Pleurocystites squamosus* (dorsal side); *p*, *p*, Two of the pectinated rhombs. C, *Pseudocrinus bifasciatus*. D, *Lepadocrinus Gebhardi*.

to the summit of the calyx. In other cases, as in *Apiocystites* and *Callocystites*, arms were present, but they were bent backwards and immovably soldered down to the surface of the calyx. The arms spring in these cases from the apex of the calyx, and are anchylosed by their dorsal surfaces to the body. On their ventral surfaces the arms are grooved by furrows which clearly correspond with the brachial grooves of the Crinoids, and on each side of these grooves is a row of pinnulæ. In one or two cases there is only a single row of pinnules, and the arm seems to have been fastened to the calyx

by one of the lateral surfaces, instead of by the dorsal surface. In one Cystidean only (viz., *Comarocystites punctatus*, Billings) are there free arms as in the true Crinoids; but further researches will doubtless show that these appendages existed in other species as well. In *Comarocystites*, however, the arms differ from those of the Crinoids in being only four in number, in not subdividing (though they carry lateral pinnæ), and in arising directly from the summit of the calyx.

Upon the upper surface of the calyx in the Cystideans are two, or sometimes three, apertures, the functions and nature of which have given rise to considerable controversy. The best known of these is a large opening which is pierced in one side of the calyx, usually near the middle of the body, but sometimes approximated to either the apex or the base. This aperture is mostly defended by a "valvular pyramid;" or, in other words, by a series of small plates, arranged in a pyramidal manner, and serving for the closure of the opening. Much difference of opinion has prevailed as to the true nature of this orifice. Von Buch believed that it was an "ovarian aperture;" Mr Billings regards it as discharging the functions of both the mouth and anus; whilst Professor Wyville Thomson, Mr Salter, and other high authorities, regard it as being the anus, and as corresponding with the proboscis of the Crinoids. That it is not an "ovarian orifice" may be regarded as certain, so that the question is narrowed to its being the anus alone, or an "oro-anal" orifice. In the living *Leskia mirabilis*, one of the Sea-urchins, both the mouth and vent are closed by converging triangular valves, which doubtless correspond with the "pyramid" of the Cystideans. This recent form, however, is not sufficient to decide the present question, since in it *both* the mouth and the anus exhibit this valvular apparatus. Upon the whole, therefore, this question must be regarded as undecided, though the analogies of recent forms would lead to the belief that the "pyramid" of the Cystideans is truly the anus, and that the mouth must be sought for between the bases of the arms, when these are present.

A second aperture is placed near the centre of the summit of the calyx, between the bases of the arms, when these exist. This opening has not been universally detected, and its true nature is doubtful. By Mr Billings it is believed to be what he terms an "ambulacral orifice;" *i.e.*, an aperture by which the ambulacral vessels passed from the interior of the shell to the exterior. The analogies of recent forms, however, would support the view that this aperture is the mouth, in which case

the "pyramid" must be the anus. There is, however, in some cases a third aperture of small size, always placed near the apex, and this has been regarded as being truly the anus.

Many Cystideans were further provided with a system of minute pores or fissures, penetrating the plates of the calyx, and usually arranged in definite groups. These groups are termed "pectinated rhombs" (fig. 84), and their exact function is doubtful. By Messrs Billings and Rose, however, they are believed, apparently with good reason, to have admitted water to the body-cavity, and to have thereby subserved a respiratory function.

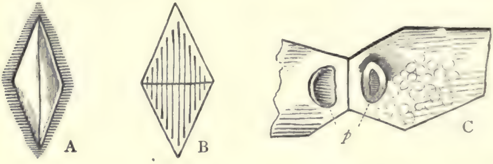


Fig. 84.—A, Pectinated rhomb of *Glyptocystites multiporus* (Billings). B, Pectinated rhomb of *Pleurocystites* (Billings). C, Two plates of *Callocystites Jewetti* (Hall), showing the pectinated rhombs (*p*). All enlarged.

As regards the distribution of the Cystideans in time, they are not only wholly extinct, but they are exclusively confined to the earlier portion of the Palæozoic period. They appear to have commenced their existence in the Upper Cambrian period, the earliest known examples being two extremely simple forms (*Trochocystites* and *Eocystites*) from the "primordial zone" of North America. Other forms have been described as occurring in the "primordial zone" of Bohemia. In the Chazy and Trenton Limestones of North America, of Llandeilo-Caradoc age (Lower Silurian), and on the same horizon in Russia, Scandinavia, and Bohemia, Cystideans are found, often in vast numbers, though in a very fragmentary condition. In the Bala Limestone (Lower Silurian) of Britain, Cystideans are abundant fossils. In the Upper Silurian (Niagara and Lower Helderberg) of North America, and on the same horizon (Wenlock and Ludlow) of Britain, Cystideans still occur, though their remains are not so plentiful. Lastly, in the Devonian Rocks occur forms which have been doubtfully referred to Cystideans, but the real nature of which is uncertain. Upon the whole, then, the Cystideans appear to have commenced in the Upper Cambrian Rocks, to have

attained their maximum of development in the Lower Silurian period, to have gradually diminished in numbers and in importance during the Upper Silurian, and to have died out at the commencement of the Devonian period, or shortly thereafter.

Of the commoner genera, *Hemicosmites* (fig. 82), *Caryocrinus*, and *Echinosphærites* have all the plates of the calyx perforated by numerous pores. *Sphæronites* has each calycine plate perforated by two pores, and *Apiocystites*, *Callocystites*, *Prunocystites*, and *Echinoencrinus* have the calycine pores arranged in rhombs upon two or three of the plates of the calyx. In *Glyptocystites* there are from ten to thirteen of these "pectinated rhombs." In *Malocystites*, *Apiocystites*, *Callocystites*, and *Pseudocrinus* the arms are recumbent and soldered to the calyx. In *Comarocystites* there were four free arms with pinnulæ. In *Lepadocrinus* the last joint of the column is very much elongated, and pointed at its extremity; and in *Agelacrinites* and some other forms the calyx appears to have been directly attached to some foreign body, and a column seems to have been wanting.

Order VI.—Blastoidea.

The *Blastoidea* or "Pentremites" are *Echinodermata* in which *the body is enclosed in an armour of closely-fitting calcareous plates, and is fixed to some foreign object by a slender column. From the summit of the calyx radiate five areas which are grooved longitudinally, and striated across, and which carry a row of jointed pinnulæ on each side.* (Fig. 85.)

The *Blastoidea* nearly resembled the Cystideans in many respects. The body or "calyx" is enclosed in a series of articulated calcareous plates consisting of three large basals, carrying five forked plates, which are usually regarded as corresponding with the "radials" of the Crinoids. At the angles of junction of the forked "radial" plates rest five smaller plates — the so-called "deltoid plates"—which converge towards the centre of the summit of the calyx. Between these deltoid plates—which are generally regarded as corresponding with the "inter-radials" of the Crinoids—are the so-called "pseud-ambulacra." The pseud-ambulacra radiate from the summit of the calyx, and the apex of each is received into the cleft formed by the bifurcation of one of the "radial" plates. Each pseud-ambulacrum is furrowed by a longitudinal groove down its centre, and is of a somewhat petaloid shape, the areas on each side of the central groove

being transversely striated. Along the lateral margins of each pseud-ambulacrum is a row of minute pores, which open into internal sacs, and are believed to have had a respiratory function. Along each side of the longitudinal groove of each pseud-ambulacrum there appears to have been attached a row of small jointed processes or "pinnulæ." The five pseud-ambulacra, radiating from the summit of the calyx, give the upper surface of the body somewhat the appearance of a flower-bud; hence the name applied to the order (Gr. *blastos*, a bud; *eidos*, form). Upon the whole, it would seem most probable that the pseud-ambulacra of *Pentremites* represent the *arms* of the Crinoids, anchylosed with the calyx, and that the longitudinal furrows of the pseud-ambulacra represent the "brachial grooves" of the Crinoids.

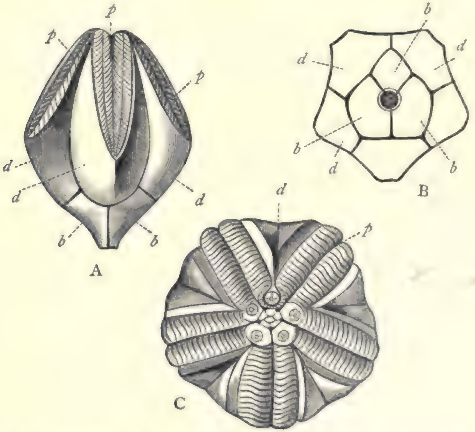


Fig. 85.—Blastoidea. A, *Pentremites pyriformis*, side-view. B, Base of the same. C, Summit of *Pentremites conoideus*. *b*, *b*, Basals; *d*, *d*, Radials; *p*, *p*, Pseud-ambulacra. C Shows the central pentagonal aperture, surrounded by the five openings at the summit of the deltoid plates. Carboniferous.

At the summit of the calyx of the *Blastoidea* are usually six apertures. One of these is larger than the others, and is placed in the centre of the calyx, at the point towards which the grooves of the pseud-ambulacra converge. This central aperture has generally been regarded as the mouth, but Mr

Billings dissents from this view. The remaining five apertures are placed at the summit of each deltoid plate, between two pseud-ambulacra. Four of the apertures are equal in size, and have generally been regarded as "ovarian;" but they are looked upon by the above-mentioned eminent authority as being connected with the respiratory system. The fifth is of larger size than the other four, and is usually regarded as partly ovarian and partly anal; but it is looked upon by Mr. Billings as "oro-anal."

Like the Cystideans, the *Blastoidea* are not only extinct, but are exclusively Palæozoic. The Cystideans, however, attained their maximum at a very early period of Palæozoic time; whereas the Pentremites flourished most abundantly in the Carboniferous seas, towards the close of the Palæozoic period. The Cystideans had nearly died out, or had become quite extinct, by the close of the Upper Silurian period; and it is a noteworthy fact that it is just at that point that the *Blastoidea* seem to make their first appearance. Very sparingly represented in the Upper Silurian Rocks, the *Blastoidea* increase largely in numbers during the Devonian period; but they attain their maximum of development in the seas of the earlier portion of the Carboniferous period. With one exceedingly problematical exception, no member of the order is known to have survived the close of the Carboniferous epoch.

Order VII.—Holothuroidea.

The last order of the *Echinodermata* is that of the Holothurians or "Sea-cucumbers," in which *the body is vermiform or slug-shaped, and the calcareous matter secreted by the integument is reduced to scattered spicules* (Synapta), *or rarely is present in the form of imbricated scales* (Psolus).

As might have been expected from the generally soft nature of their integuments, the Holothuroids are hardly known as fossils, and they merely require to be mentioned here. The only remains referred with any probability to this order are certain calcareous spicula which have been found in deposits of both Mesozoic and Tertiary age, and which have been regarded as belonging to a *Synapta*, and the shield of a species of *Psolus* which has been found in Post-Tertiary deposits in Bute.

CHAPTER XIII.

SUB-KINGDOM IV.—ANNULOSA.

Fossil Annelida.

Sub-kingdom Annulosa.—The Annulose animals are distinguished by the possession of *a body which is composed of numerous segments arranged longitudinally one behind the other. A nervous system is always present, and consists of a double chain of ganglia running along the ventral surface of the body and traversed anteriorly by the gullet. The limbs (when present) are turned towards that side of the body upon which the chief masses of the nervous system are situated.*

The sub-kingdom *Annulosa* may be divided into two primary sections, according as the body is provided with articulated appendages or not; these divisions being known respectively as the *Arthropoda* (or *Articulata*) and *Anarthropoda*. The first of these comprises the Crabs, Lobsters, and the like (*Crustacea*), the Spiders and Scorpions (*Arachnida*), the Centipedes and Millipedes (*Myriapoda*), and the true Insects (*Insecta*). The latter comprises the Spoon-worms (*Gephyrea*), the Leeches (*Hirudinea*), the Earth-worms (*Oligochæta*), the Tube-worms (*Tubicola*), and the Sand-worms or Sea-worms (*Errantia*); the last four groups constituting the class of the Ringed Worms or *Annelida*.

Regarded as a whole, the great Annulose sub-kingdom seems to have commenced at least as early as the *Echinodermata* and the *Cœlenterata*. Both the Anarthropodous and Arthropodous divisions of the sub-kingdom are represented in the Upper Cambrian; and the former, at any rate, is represented in the Lower Cambrian period, along with the earliest traces of life known to us, except the *Eozoön* of the Laurentian Series.

Annelida.

In the Anarthropodous division of the *Annulosa* the locomotive appendages are never distinctly jointed or articulated to the body; and the integument, though usually capable of secreting chitine or horny matter, is almost always quite soft and flexible. The Spoon-worms (*Gephyrea*), and two orders of the Annelides (viz., the Leeches and the Earth-worms), are wholly unknown in the fossil condition, and need not be considered here. There remain only two orders of the Annelides

(viz., the Tubeworms or *Tubicola*, and the Sand-worms or *Errantia*) which come under the notice of the palæontologist, and neither of these requires much notice. In both orders, as throughout the division, the integument is more or less soft, and there are no internal hard structures; hence it is more than doubtful if we have any example of the fossilised body of these creatures, though such have been alleged to occur. The Tubicolous Annelides, however, protect themselves by a tube of lime, sand, or adventitious particles, and these investing tubes are often preserved in the fossil condition. The Errant Annelides, again, have left traces of their past existence in the form of filled-up burrows or meandering trails upon the soft sand and mud of the sea-bottom; and from these we know that the Annelides commenced their existence at least as early as the Lower Cambrian period, obscure traces of their presence having been even detected in the Laurentian Series.

ORDER TUBICOLA.—The Tubicolous Annelides are distinguished by the fact that *the body is protected by a tube within which the animal can withdraw itself by means of tufts of bristles carried on the sides of the body. The gills are placed on or near the head, generally in two lateral tufts; hence the name of "Cephalobranchiate Annelides," applied to this order* (fig. 86).

The protecting tube of the Tubicolous Annelides may be composed of carbonate of lime (*Serpula*), of grains of sand (*Sabellaria*), or of sand, pieces of shell, and other adventitious particles cemented together by a glutinous secretion from the body (*Terebella*); or it may be simply membranaceous or leathery (*Sabella*). Sometimes the tube is free and non-adherent (*Pectinaria*); more commonly it is attached to some sub-marine object by its apex or by one side (*Serpula* and *Spirorbis*). Sometimes the tube is single (*Spirorbis*); sometimes the animal is social, and the tubes are clustered together in larger or smaller masses (*Sabellaria*).

Fig. 86.—Tubicola. *a Serpula contortuplicata*, showing the branchiæ and operculum; *b Spirorbis communis*.

When the tube is calcareous, it presents certain resemblances to the shells of some of the Molluscs, such as *Vermetus* and *Dentalium*. In the living state it is easy to make a distinction between these, for the Tubicolar Annelides are in no way

organically attached to their tubes, whereas the Molluscs are always attached to their shell by proper muscles. In the fossil condition, however, it may be very difficult to refer a given calcareous tube to its proper place. As a general rule, however, the calcareous tubes of Annelides, such as *Serpula*, are less regular and symmetrical than those of *Vermetus*, whilst the latter is partitioned by shelly septa, which do not exist in the former. Again, the tube of *Dentalium* is open at both ends, whereas it is closed at one extremity in the *Serpulæ*. In the Annelidous genus *Ditrupa*, however, the tube is open at both ends, so that this distinction is one not universally applicable.

Tubicolar Annelides are known from the Silurian Rocks upwards, almost every great period having representatives of the order, though many of the fossils referred to this group are of a more or less problematical nature. The genus *Spirorbis* has survived from the Upper Silurian period to the present day; and forms very nearly allied to, if not actually identical with, the recent *Serpulæ*, are found in almost all formations, beginning with the Silurian.

The chief Palæozoic genera of *Tubicola* are *Cornulites*, *Conchicolites*, *Serpulites*, *Trachyderma*, *Spirorbis* (*Microconchus*), and *Serpula*. The genus *Cornulites* (fig. 87) is Silurian, and the best known species is *C. serpularius*. In this singular form the tube is of considerable length — often three or four inches—with a wide aperture at one end, and tapering gradually to its opposite extremity, which is often curved, and seems to have been attached to some solid body. The tube is calcareous, with very thick walls, the substance of which is composed of a number of cellular cavities. Externally the tube is ringed with transverse annulations, and marked with fine longitudinal striæ. The internal cast of the tube has the form of a series of inverted conical rings, of small width, arranged in an imbricated manner. The tube appears to have been solitary, and is rarely found attached.

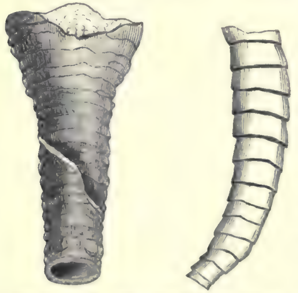


Fig. 87.—*Cornulites serpularius*. Upper Silurian.

In the genus *Conchicolites* (fig. 88) we have a much smaller Annelide, living socially, and forming masses of clustered tubes growing attached to dead shells in Lower Silurian strata. As in *Cornulites*, the tube of *Conchicolites* appears to have been calcareous, but it is comparatively thin, and has none of the vesicular structure so characteristic of the former. The tube of *Conchicolites* is made up of a series of short conical rings, inserted into one another in an imbricated manner, with their broader ends turned away from the mouth of the tube. It is worthy of notice that the casts of *Conchicolites*, from their possession of the above structure, exhibit a close resemblance to the shells of the Silurian genus *Tentaculites;* whilst *casts* of the shells of some species of the latter are absolutely undistinguishable, if fragmentary, from casts of the tubes of the former. This is a remarkable fact, since *Tentaculites* has often been regarded as a genus of Tubicolar Annelides; but there are strong reasons for believing that it is truly referable to the *Mollusca*, and belongs to the order of the Pteropods.

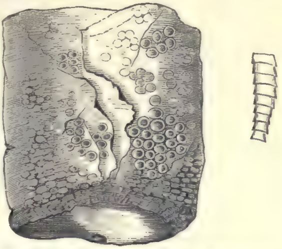


Fig. 88.--*Conchicolites gregarius*, growing upon the shell of an *Orthoceras*. Lower Silurian.

The genus *Serpulites* was instituted by Murchison for certain smooth semi-calcareous tubes, often of great length, and apparently unattached, which occur in the Silurian series. These tubes in some species reach a length of over a foot, with a diameter of an inch, and their true nature is very doubtful. The genus *Trachyderma*, again, was proposed by Phillips for the casts of membranous flexible tubes which are found in the Silurian rocks. These are transversely wrinkled or plaited, and though the tube itself has disappeared, there can be little doubt entertained as to their Annelidous nature.

The genus *Spirorbis* (fig. 89) is characterised by the possession of a shelly calcareous tube, which is coiled into a flat spiral, one side of which is cemented to some foreign body. The spiral may be either right-handed or left-handed, and the shell generally occurs in numbers together, attached to dead shells or to the remains of plants. The genus commences to be represented in the Upper Silurian Rocks, in which *S. Lewisii* is an abundant fossil. Other species occur in the Devonian,

and the little *S. carbonarius* (fig. 89) is a common species in the Carboniferous Rocks, whilst more than one form has been described from the Permian series. The genus continues to

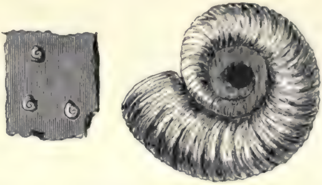


Fig. 89.—*Spirorbis* (*Microconchus*) *carbonarius*; natural size, attached to a fossil plant, and magnified. Carboniferous. (After Dawson.)

be well represented in both Mesozoic and Tertiary deposits; and living forms, apparently little different from the fossil ones, abound in recent seas.

The genus *Serpula* (fig. 90) possesses a long shelly tube, usually more or less tortuous, sometimes solitary, sometimes aggregated, and fixed to some foreign body by part of its surface. Species of this genus have been described from the Upper Silurian, Devonian, and Carboniferous formations. In the Trias some species occur, and many forms are known from the Oolitic and Cretaceous formations, whilst they are equally numerous in the Tertiary series.

Fig. 90.—*Serpula flagellum.* Oxford Clay. (Jurassic.)

Of the other fossils referred to the Tubicolar Annelides, the only one which needs notice is the genus *Ditrupa.* The tube in this genus is unattached, open at both extremities, and very closely resembling the shell of a *Dentalium.* This genus does not seem to

have come into existence till the close of the Cretaceous period; but it is found in great abundance in the London Clay (Eocene) and the Crag (Pliocene).

ORDER ERRANTIA.—The Errant Annelides are characterised by the fact that *the body is furnished with lateral tubercles carrying tufts of bristles. The animal leads a free life, and is not confined to a tube. The gills are placed along the back or sides of the body; hence the name of "Dorsibranchiate Annelides," often applied to this order* (fig. 91).

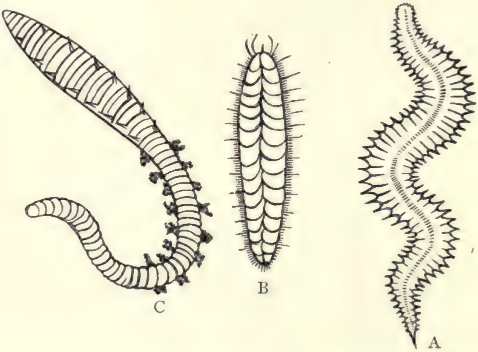


Fig. 91.—Errant Annelides. A, Hairy-bait (*Nephthys*); B, Sea-mouse (*Aphrodite*); C, Lob-worm (*Arenicola*). (After Gosse.)

Possessing no hard structures, the Errant Annelides are hardly capable of being preserved in a fossil state. Certain fossils, however, have been supposed to be the bodies of these animals in a petrified state; but it is very difficult to believe that such is the true nature of the remains in question, and it is almost certain that they are really nothing more than the "tracks" of sea-worms. On the other hand, the Errant Annelides are abundantly represented by their trails upon old sea-bottoms or their burrows in sand or mud; remains of which occur in all formations, almost, from the Lower Cambrian up to the present day.

The burrows of Annelides, as a matter of course, run in a direction more or less opposed to the surfaces of the laminæ of the rock, being often quite vertical. Sometimes such burrows are hollow, but they are more commonly filled up by the

matrix of the rock. The most important genera which have been founded upon remains of this kind are *Scolithus*, *Histioderma*, and *Arenicolites*, all of which occur in rocks of Cambrian age. *Scolithus* is founded upon long burrows, which are nearly straight, and descend vertically through the rock (fig. 92). *Histioderma* is a somewhat curved burrow, from one to nearly four inches in length, terminating by a trumpet-shaped opening, which is placed in the centre of a small mound. *Arenicolites* includes very small burrows which form loops, opening on the surface by two apertures placed close to one another. The mouths of these burrows are thus placed in pairs, one being believed to be an aperture of entrance for the worm, the other of exit. The nature of none of these fossils

Fig. 92.—Annelide-burrows (*Scolithus Canadensis*), from the Potsdam Sandstone (Upper Cambrian). (After Billings.)

is wholly free from doubt; but the other genera, which have been regarded as formed by burrowing Annelides, are still more obscure and uncertain.

As regards the surface-tracks and trails of Errant Annelides, much difference of opinion exists, and the whole subject is shrouded in obscurity. Many of these tracks were regarded by their describers as being actually the body of the worm, as in *Crossopodia* (fig. 93). Others, as *Gordia* and *Myrianites*, are undoubtedly tracks of some animal, but there is no evidence as to their having been produced by Annelides. Others, again, such as *Palæochorda*, which are also almost certainly the trail of some marine animal, have been described as the remains of plants. A few of these fossils may truly be of

a vegetable nature, whilst as to others (such as *Nereites*) no certain conclusion can be arrived at. Upon the whole, it would be safest to adopt Mr. Salter's proposal, and refer all these remains provisionally to the artificial genus *Helminthites*,

Fig. 93.—*Crossopodia Scotica*, an Annelide track. Silurian. (After M'Coy.)

retaining *Scolithus* for the burrows. As regards the distribution of these remains, it is sufficient to say that they occur more or less abundantly in almost all strata of a suitable mineral character from the Cambrian Rocks upwards.

CHAPTER XIV.

ARTHROPODA.

CRUSTACEA.

DIVISION ARTHROPODA, OR ARTICULATA.—The members of this division of the sub-kingdom *Annulosa* are distinguished from the preceding division of the *Anarthropoda* by the possession of *jointed appendages, articulated to the body. The body is composed of a series of segments or "somites," arranged along a longitudinal axis; each segment occasionally, and some always, being provided, at some period of life or other, with articulated appendages. Both the segmented body and the articulated limbs*

are more or less completely protected by an external skeleton formed by the deposition of horny (chitinous) matter in the integument.

The division *Arthropoda* includes four great classes of animals which are very generally spoken of as the "Articulate Animals." These classes are the *Crustacea* (Lobsters, Crabs, &c.), the *Arachnida* (Spiders, Scorpions, &c.), the *Myriapoda* (Centipedes and Millipedes), and the *Insecta* (Insects). All these classes came into existence in the Palæozoic period, the division being represented by Crustaceans as early as the Upper Cambrian at any rate, and doubtfully in the Lower Cambrian. Owing to the fact that the Crustaceans alone lead an habitually aquatic life, the remains of this class, as might be expected, preponderate largely over those of the other three. The air-breathing classes of the *Arachnida*, *Myriapoda*, and *Insecta*, naturally, have not left abundant traces of their existence in past time, a state of things which is assisted by the nature of their integuments, which are rarely as hard and resisting as those of the Crustaceans.

CLASS I.—CRUSTACEA.

The *Crustaceans* are *Articulate animals in which the breathing organs (when distinct) are in the form of gills, and the mode of existence is almost always more or less aquatic. The body is protected by a chitinous or sub-calcareous exoskeleton or "crust," and the number of pairs of articulated limbs is generally from five to seven. Some of the locomotive appendages are often carried upon the segments of the abdomen, and there are two pairs of jointed feelers or "antennæ."*

The body of a typical Crustacean, such as a Lobster (fig. 94), consists of a definite number of somites placed one behind the other, and divisible into three regions—a *head*, *thorax*, and *abdomen*. Most authorities regard the body as being typically composed of twenty-one somites, of which seven go to the head, seven to the thorax, and seven to the abdomen. All these somites, except the last, may be provided with a pair of appendages each. The last segment of the abdomen, however, never carries any appendages. This segment is known as the "telson" (fig. 94, 1, *t*), and it is variously regarded as a somite without appendages, or as an *unpaired appendage* placed in the middle line of the body. If this latter view be adopted, the body of a typical Crustacean will consist of only twenty segments, instead of twenty-one. The telson is very

greatly developed in some Crustaceans, such as the King-crabs, and less so in the extinct *Eurypterida*.

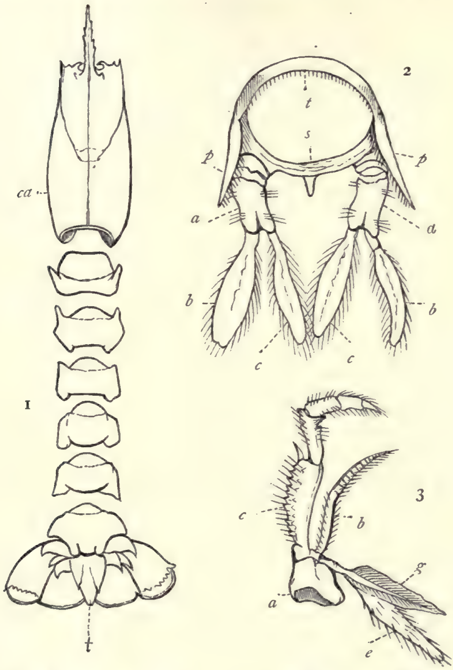


Fig. 94.—Morphology of Lobster. 1. Lobster with all the appendages, except the terminal swimmerets, removed, and the abdominal somites separated from one another. *ca* Carapace; *t* Telson. 2. The third abdominal somite separated. *t* Tergum; *s* Sternum; *p* Pleuron; *a* Propodite; *b* Exopodite; *c* Endopodite. 3. One of the last pair of foot-jaws or maxillipedes. *e* Epipodite; *g* Gill; the other letters as before.

Generally speaking, a greater or less number of the somites are amalgamated together, rendering it difficult to recognise their existence unless they bear appendages — each pair of appendages indicating a separate somite. Very commonly the segments of the head and thorax are welded together into a single mass, which is termed the "cephalothorax," and which

really consists of fourteen coalescent segments. The cephalothorax is generally covered by a great shield or buckler, which is termed the "carapace" (fig. 94, 1, *ca*), which is produced by an enormous development of the dorsal walls of one or two of the cephalic somites.

Each segment of the body may be regarded as essentially composed of a convex upper plate, termed the "tergum," which is closed below by a flatter plate, called the "sternum," the line where the two unite being produced downwards and outwards into a plate which is called the "pleuron," or "pleura" (fig. 94, 2).

Strictly speaking, the composition of the typical somite is considerably more complex, each of the primary arcs of the somite being really composed of four pieces. The tergal arc is composed of two central pieces, one on each side of the middle line of the body, united together, and constituting the "tergum" proper. The superior arc is completed by two lateral pieces, one on each side of the tergum, which are termed the "epimera." In like manner the ventral or sternal arc is composed of a central plate, composed of two pieces united together in the middle line, and constituting the "sternum" proper, the arc being completed by two lateral pieces, termed the "episterna." These plates are usually more or less completely anchylosed together, and the true structure of the somite in these cases is often shown by what are called "apodemata." These are septa which proceed inwards from the internal surface of the somite, penetrating more or less deeply between the various organs enclosed by the ring, and always proceeding from the line of junction of the different pieces of the segment (fig. 95).

Each somite of the body may bear a pair of appendages, and these appendages are very much modified in different parts of the body, in order to fulfil different functions. Usually, however, a common morphological type may be recognised in the appendages of the *Crustacea*, though certain elements of this type are often wanting or much modified. *Typically*, the appendages of the *Crustacea* consist of an undivided basal portion or "propodite," giving origin to two diverging joints, of which the inner is called the "endopodite," whilst the outer is known as the "exopodite." In such an appendage as the "swimmeret" of a Lobster (fig. 94, 2), these fundamental parts are readily recognisable; but either the exopodite or endopodite, or both, may be wanting, or they may be very much modified in shape and form.

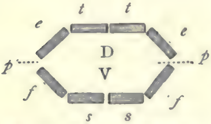


Fig. 95.—Theoretical figure illustrating the composition of the tegumentary skeleton of the Crustacea (after Milne-Edwards). D Dorsal arc; *t t* Tergal pieces; *e e* Epimeral pieces; V Ventral arc; *s s* Sternal pieces; *f f* Episternal pieces; *p p* Insertion of the extremities.

It is impossible to give any general view of the appendages of a Crustacean; but it may be as well to name the appendages which are present in one of the higher forms, such as the Lobster, in which all the somites, except the telson, carry a pair of appendages each. The somites of the head and thorax are amalgamated into a single mass, termed the "cephalo-thorax," which is protected above by the "carapace," and carries the appendages on its lower surface. The *first* segment of the head carries a pair of eyes, which are "compound," and are borne upon long stalks, formed by the propodite of the appendage. The *second* segment of the head carries a pair of small jointed feelers, which are known as the "lesser antennæ" or "antennules." Each consists of a short propodite, and a much-segmented endopodite and exopodite, which are nearly of equal length. The *third* segment of the head carries a pair of very long feelers, which are known as the "great antennæ." Each consists of a short propodite and a long and jointed endopodite, with a rudimentary exopodite. The *fourth* segment of the head carries a pair of jaws, which are known as the "mandibles." Each mandible consists of a large propodite, with no exopodite, but with a small endopodite, which is known as the "mandibular palp." Between the bases of the mandibles also is placed the aperture of the mouth, which is bounded *in front* by a plate, known as the "labrum" (upper lip) or "hypostoma," and *behind* by a forked plate, known as the "labium" (lower lip) or "metastoma." The *fifth* segment carries another pair of jaws, which are known as the first pair of "maxillæ;" whilst the *sixth* segment carries another pair of the same, known as the second pair of "maxillæ." The *seventh* and last segment of the head carries the first of three pairs of what are generally known as "foot-jaws" or "maxillipedes." Each foot-jaw is merely an ordinary limb, consisting of propodite, exopodite, and endopodite, but modified to assist in mastication. The *eighth* segment (the first of the thorax) carries a second pair of foot-jaws, and the *ninth* segment (the second of the thorax) bears a third pair of the same. The *tenth* segment (the third of the thorax) carries a pair of jointed limbs, consisting of propodite and endopodite alone, without any exopodite. These limbs are greatly developed, and their extremities form a pair of pincers or "chelæ," so that they constitute the "nipping-claws" of the Lobster. The *eleventh* segment (the fourth of the thorax) carries a second pair of limbs, also "chelate," but much smaller than the preceding; and the *twelfth* segment (the fifth of the thorax) carries another pair of the same. The *thirteenth* segment (the sixth of the

thorax) carries a pair of limbs like the preceding, but with simply-pointed extremities; and the *fourteenth* segment (the last of the thorax) carries another pair of the same; so that there are altogether five pairs of ambulatory limbs, carried respectively by the 10th, 11th, 12th, 13th, and 14th somites of the body; or, in other words, by the last five segments of the thorax. Of the seven segments of the abdomen—completing the total of twenty-one—the first six carry each a pair of appendages, which are used as swimming organs, and which are termed the "swimmerets." Each swimmeret (fig. 94, 2) consists of a propodite and a flattened exopodite and endopodite; and the last pair is greatly widened out and expanded, forming with the telson a powerful swimming-tail. The telson or last abdominal segment carries no appendages, and is simply placed between the last pair of swimmerets.

As regards the general distribution of the *Crustacea* in time, remains of the class are comparatively abundant in all formations except the very oldest; as might have been expected from the generally chitinous or sub-calcareous nature of their integuments and their aquatic habits. Owing also to their habit of periodically casting their shell, a single individual may leave repeated traces of himself, and the number of fossils may considerably exceed that of the individuals which actually underwent fossilisation. The Crustaceans appear to have commenced their existence in the Cambrian period, remains of members of this class being tolerably abundant in the higher portion of this formation. The Palæozoic formations, taken as a whole, are characterised by the predominance of the orders *Trilobita*, *Eurypterida*, *Ostracoda*, and *Phyllopoda*, of which the two former are exclusively confined to this period. All the other orders of *Crustacea*, which have left any traces of their past existence at all, appear to have come into existence before the close of the Palæozoic period. Upon the whole, however, there has been a marked progression in proceeding from the older formations to the present day. The Trilobites and Eurypterids of the older Palæozoic Rocks, though highly organised so far as their type is concerned, are in many respects inferior to later forms, whilst they present some striking points of resemblance to the larval forms of the higher groups. The great group of the Stalk-eyed Crustaceans—undoubtedly the highest of the entire class—is not represented at all till we reach the Carboniferous Rocks: and it is not till we come into the Secondary period that we find any great development of this group, whilst its abundance increases to a marked extent in the Tertiary period, and it attains its maximum at the

present day. Similarly, of the two sub-orders of the *Merostomata*, the *Eurypterida* are confined to the earlier portion of the Palæozoic period, whilst the more highly organised and less larval King-crabs (*Xiphosura*) did not make their appearance till the Eurypterids had disappeared, at the close of the Carboniferous period.

The following table shows the orders of the *Crustacea*, and a short account will be given of the distribution in time of those which are known to occur as fossils. The structure also of the extinct groups will be shortly described. The orders marked with an asterisk do not occur as fossils, or only doubtfully so, and will not be considered here.

TABULAR VIEW OF THE DIVISIONS OF THE CRUSTACEA.

Sub-class I. EPIZOA (*Haustellata*).
Order 1. *Ichthyophthira*.*
„ 2. *Rhizocephala*.*

Sub-class II. CIRRIPEDIA.
Order 3. *Thoracica*. { Balanidæ. Verrucidæ. Lepadidæ.
„ 4. *Abdominalia*.*
„ 5. *Apoda*.*

Sub-class III. ENTOMOSTRACA.
Order 6. *Ostracoda*.
„ 7. *Copepoda*.* } *Legion*, Lophyropoda.
„ 8. *Cladocera*.*
„ 9. *Phyllopoda*.
„ 10. *Trilobita*. } *Legion*, Branchiopoda.
„ 11. *Merostomata*.

Sub-class IV. MALACOSTRACA.
Division A. EDRIOPHTHALMATA.
Order 12. *Læmodipoda*.*
„ 13. *Isopoda*.
„ 14. *Amphipoda*.

Division B. PODOPHTHALMATA.
Order 15. *Stomapoda*.
„ 16. *Decapoda*.
Tribe *a*. *Macrura*.
„ *b*. *Anomura*.
„ *c*. *Brachyura*.

SUB-CLASS CIRRIPEDIA.

Animal free when young, but permanently attached in the adult condition to some foreign body by the anterior extremity of the metamorphosed head. The visceral cavity of the adult protected by a calcareous shell of several pieces, or by a coriaceous envelope. Abdomen free. Thoracic segments usually carrying six pairs of forked ciliated limbs.

The *Cirripedia* include three orders, of which only the order *Thoracica* has ever been found in a fossil condition, or is ever likely to be so. In this order are the common Acorn-shells (*Balanidæ*) and Barnacles (*Lepadidæ*), in which the body is protected by a more or less complete calcareous shell. The Acorn-shells are generally known as the "Sessile Cirripedes," because the shell is directly attached by its base to some foreign body, whereas the Barnacles are commonly known as the "Pedunculated Cirripedes," because the shell is supported upon a stalk or "peduncle." Besides these, the order *Thoracica* comprises a third family, that of the *Verrucidæ*, in which the shell resembles that of the *Balanidæ* in being sessile, but differs in being unsymmetrical, and in some other particulars.

It is with the *shell* of the Cirripedes that the palæontologist has to deal; and we may, therefore, consider briefly the chief parts of the shell in the Sessile and Pedunculated Cirripedes respectively. It will not be necessary, however, to enter into minute details on this complicated subject, and it will be sufficient to indicate the leading facts of importance.

In the symmetrical Sessile Cirripedes or *Balanidæ*, commonly known as Acorn-shells, the animal is protected by a calcareous shell formed by calcifications within the walls of the first three cephalic segments. The animal is placed within the shell, head downwards, and is fixed to the centre of a shelly or membranous plate, which closes the lower aperture of the shell, and which is termed the "basis" (fig. 96 A, *l*). The "basis" is fixed by its outer surface to some foreign object, and is sometimes compact, sometimes porous. Above the basis rises a limpet-shaped, conical, or cylindrical shell, which is open at the top, but is capable of being completely closed by a pyramidal lid or "operculum." Leaving the operculum out of consideration at present, the sides of the shell are seen to be composed of from four to eight separate pieces, valves, or, as they are technically called, *compartments*. These compartments are usually closely contiguous by their lateral margins, and are separated by lines of division or "sutures;" but they are sometimes anchylosed together. Each compartment consists of a central portion, which is termed the "paries" (fig. 96, B *p*), which is attached by its base to the "basis" of the shell. The "paries" grows downwards, so that the whole shell increases by additions made round the base. The paries of each compartment is flanked by wing-like portions, which differ from the paries in appearance, and are called "radii" and "alæ," according to their shape (fig. 96, B, C). Sometimes the paries has a "radius" on both sides, sometimes

"alæ" on both sides, and sometimes an ala on one side and a radius on the other.

The separate compartments of the shell receive special names according to their position. The compartment at the end of the shell where the animal thrusts out its cirrated limbs, is called the "carina" (fig. 96, A); and the compartment immediately opposite to this "rostrum." The remaining compartments are "lateral," the one nearest the carina "carino-lateral," the one nearest the rostrum "rostro-lateral," and the middle one simply "lateral" (fig. 96, A); but the three rarely coexist.

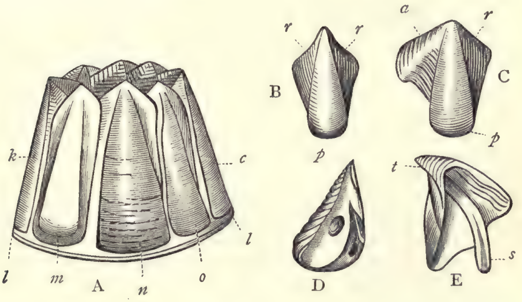


Fig. 96.—Shell of Balanidæ. A, Diagram of the shell of *Balanus*; *l*, *l* Basis; *c* Carina; *k* Rostrum; *m* Rostro-lateral compartment; *n* Lateral compartment; *o* Carino-lateral compartment. B, Compartment with two radii (*r*, *r*) flanking the paries (*p*). C, Compartment with a radius (*r*) on one side, and an *ala* (*a*) on the other side of the paries. D, Internal view of the scutum. E, Internal view of the tergum, showing the spur (*s*) and the beak (*t*). (After Darwin.)

The "operculum" or lid of the shell consists of two pairs of valves, known as the "scuta" and "terga," forming a little pyramid or cone, attached within the orifice of the shell by a membrane. Each scutum opens and shuts against its fellow along one margin (the "occludent" margin), and articulates with one of the terga along the opposite margin. Similarly, each tergum opens and shuts against its fellow along one margin (the "carinal" margin), and articulates with one of the scuta along the opposite margin. The apex of the terga (fig. 96, E) often forms a prominent beak, and the basal margin is furnished with a process or "spur." The scuta and terga are not only movable, but are furnished with proper depressor muscles.

As regards the distribution of the *Balanidæ* in time, the oldest known representative of the family, so far as is certainly known, has been indicated by Mr Seeley as occurring in the Lias, and has been made the type of a new genus under the name of *Zoocapsa.* So far as is known, no member of the group occurs in any Palæozoic deposit; and negative evidence is in this case of considerable value, as the *Balani* possess a shell which is readily preserved, whilst they adhere to all sorts of marine bodies. With the above-mentioned exception (which may, perhaps, be referred to the *Verrucidæ*), no fossil Balanoid has hitherto been discovered in sediments older than the commencement of the Tertiary period. The genus *Balanus* is the earliest of the group, and appears under several specific forms in the Eocene Rocks. In the Miocene and Pliocene deposits, the *Balanidæ* are abundantly represented by *Balanus* itself, and in the latter by the genera *Acasta*, *Pyrgoma*, and *Coronula.*

The remaining family of the Sessile Cirripedes is that of the *Verrucidæ*, comprising only the single genus *Verruca.* In many respects the *Verrucidæ* approach the *Balanidæ*, but the shell is composed of six valves only, and is unsymmetrical, whilst the scuta and terga (forming the operculum), though movable, are not furnished with a depressor muscle. The *Verrucidæ* appear, so far as is known, to have commenced their existence towards the close of the Secondary period, the Chalk having yielded one species. *Verruca Strömia* is found in the Coralline and Red Crags (Pliocene), in Glacial deposits, and in existing seas.

The third family of the *Cirripedia Thoracica* is that of the *Lepadidæ* or Pedunculated Cirripedes, commonly known as "Barnacles." In these (fig. 97) the animal differs from the Sessile Cirripedes in having its anterior extremity greatly elongated, forming a stalk or "peduncle" by which the animal is fixed to some foreign object. At its free extremity the peduncle bears the "capitulum," which corresponds to the shell of the Balanoids, and is composed of various calcareous pieces, united by a membrane, moved upon one another by appropriate muscles, and protecting in their interior the body of the animal with its various appendages. The peduncle is cylindrical, of varying length, flexible, and furnished with proper muscles. In some species the peduncle is naked, and cannot be preserved in the fossil condition; but in other cases the peduncle is furnished with calcareous scales (*Loricula* and *Turrilepas*, fig. 99), in which case it is readily preserved. The "capitulum" (fig. 98), as before said, corresponds with the

shell of the *Balani*, and is generally much flattened. It consists ordinarily of five or more valves united to one another by membrane, usually with marked interspaces; but the valves may be rudimentary or wanting, and the entire capitulum may be membranous. The parts of the capitulum correspond ideally with the parts of the shell in the Balanoids. In the latter, however, the shell is for the most part composed of the "compartments," and the "operculum" is comparatively small and insignificant. In the Lepadoids, on the other hand, the valves which correspond with the operculum of the Balanoids are disproportionately developed, and the valves which correspond with the compartments of the Balanoids are much less conspicuous, and are often partially absent. The most important and persistent of the valves are the "scuta" (fig. 98, *b*), which protect the front part of the body, and correspond with the valves bearing the same name in the operculum of the Balanoids. The next most important are the "terga" (fig. 98, *a*), which protect the dorso-lateral surface. A pair of scuta and a pair of terga are present, and these are the largest of all the valves. The "carina" and "rostrum" are placed along the edges of the capitulum, the former being much the most important, and there may be a "sub-carina" and "sub-rostrum." The remaining valves, with the carina and rostrum, correspond with the proper shell of the Balanoids; but they are often wanting or rudimentary, and they require no further consideration here.

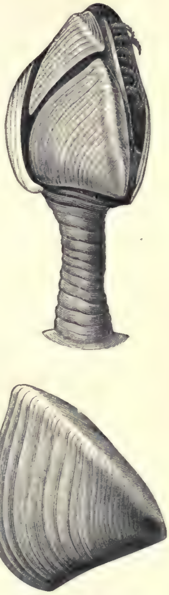


Fig. 97.—*Anatifa lepas*, a recent Pedunculated Cirripede. The lower figure shows the scutum detached.

As regards the distribution of the Pedunculated Cirripedes in time, until recently no member of the family was certainly known to have existed in the Palæozoic period. Mr Henry Woodward, however, has described a very interesting form from the Upper Silurian Rocks, under the name of *Turrilepas* (fig. 99, A). In this singular fossil the peduncle was furnished

with intersecting rows of plates, as in *Loricula*. These plates, when detached and occurring in an isolated condition, might very readily be mistaken for the shells of Pteropods. The genus is known both from the Wenlock Limestone of Dudley and the Ludlow Rocks of the Pentland Hills near Edinburgh. The Devonian, Carboniferous, and Permian formations have as yet yielded no certain traces of Pedunculated Cirripedes, if we reject, as we apparently must, the *Aptychus* of the Carboniferous rocks, referred here by M. D'Orbigny.

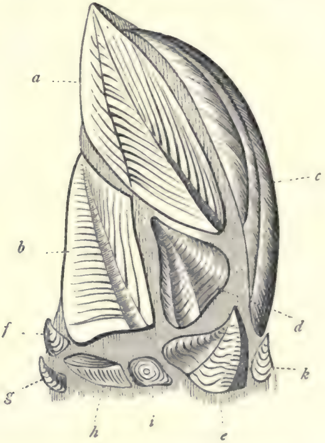


Fig. 98.—Capitulum of a Pedunculated Cirripede. *a* Tergum ; *b* Scutum ; *c* Carina ; *d* Upper latus ; *e* Carino-latus ; *f* Rostrum ; *g* Sub-rostrum ; *h* Rostral latus ; *i* Infra-median latus ; *k* sub-carina. (After Darwin.)

With the exception of the very ancient *Turrilepas*, the oldest pedunculated Cirripedes belong to the genus *Pollicipes*, species of which have been discovered in the Rhætic beds (Upper Trias), and in the Lower Oolites (Stonesfield Slate). In the Cretaceous period, "the Lepadidæ arrived at their culminant point; there were then three genera, and at least thirty-two species, some occurring in every stage of this system" (Darwin). In the Tertiary rocks are a few species of *Scalpellum* and *Pollicipes;* but no species of the now existing and widely distributed

genus *Lepas* or *Anatifa* has as yet been certainly detected in a fossil condition (Darwin), though D'Orbigny states that he has

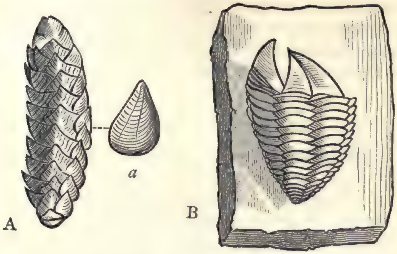


Fig. 99.—A, *Turrilepas Wrightii.* Upper Silurian. (After Woodward.) *a* A plate of the same magnified. B, *Loricula pulchella.* Chalk. (After Darwin.)

discovered a representative of this genus in the Miocene Tertiary.

CHAPTER XV.

CRUSTACEA—Continued.

SUB-CLASS ENTOMOSTRACA.

THE Entomostracous Crustaceans are defined by Professor Rupert Jones as follows:—"*Animal aquatic, covered with a shell, or carapace, of a horny consistency, formed of one or more pieces, in some genera resembling a cuirass or buckler, and in others a bivalve shell, which completely or in great part envelops the body and limbs of the animal; in other genera the animal is invested with a multivalve carapace, like jointed plate-armour; the branchiæ are attached either to the feet or to the organs of mastication; the limbs are jointed, and more or less setiferous. The animals, for the most part, undergo a regular moulting or change of shell, as they grow; in some cases this amounts to a species of transformation.*"

The orders commonly included in the sub-class *Entomostraca* are the *Ostracoda*, *Copepoda*, *Cladocera*, *Phyllopoda*, *Trilobita*, and *Merostomata* (comprising the sub-orders *Xiphosura* and *Eurypterida*). Of these, the *Copepoda* and *Cladocera* may

be left out of consideration, as they are not certainly known to occur in the fossil condition. There are also good reasons for the belief that the Trilobites should be placed amongst the Malacostracous Crustaceans, in or near the order *Isopoda*. In the absence, however, of unassailable evidence, the Trilobites may be safely retained in the vicinity of the Phyllopods, to which they show undoubted affinities.

Order Ostracoda.

Minute Crustaceans having the entire body enclosed in a shell or carapace, which is composed of two valves united along the back by a membrane. The valves are capable of being closed by an adductor muscle, the insertion of which is marked in the interior of each valve by a tubercle, pit, or group of spots, or by both spots and a pit. The branchiæ are attached to the posterior jaws, and there are only two or three pairs of feet, which subserve locomotion, but are not adapted for swimming.

Of the living Ostracode Crustaceans, a great many inhabit fresh waters (*Cypris*); others live in fresh or in brackish waters (*Candona*); lastly, others are exclusively confined to the sea (*Cythere* and *Cypridina*). They generally swarm in the localities in which they occur, and from their habit of periodically shedding their valves, considerable accumulations of their shells may be formed under favouring circumstances.

It is only the carapace-valves of the Ostracode Crustaceans that are preserved in the fossil condition; and the general form of the carapace is often very similar in different genera. Hence, the palæontologist has to rely, in the discrimination of these minute fossils, upon small variations of shape, differences in the thickness of the valves, the characters of the edges of the valves, or the manner in which they are hinged to one another, or, lastly, the surface-ornamentation. Partly for this reason, and partly because the number of known fossil *Ostracoda* is very large, it will not be advisable here to do more than give an outline of the general distribution of the order in time.

The Ostracode Crustaceans appear to have been amongst the earliest representatives of their class, abounding as they do in many Lower Silurian deposits. Amongst the more important genera which are represented in the Silurian Rocks may be mentioned *Primitia* (fig. 100, *a*), *Leperditia*, *Beyrichia*, *Entomis*, *Cypridina*, *Cytherella*, *Cythere*, and *Bairdia*. Of these the genus *Primitia* is exclusively confined to the Silurian rocks, whilst the great genus *Leperditia* arrived here at its greatest development. On the other hand, the genera *Cytherella*,

Cythere, and *Bairdia* are represented by species now living. Presumably all these genera were marine, and we know that this was the case with many of them. The Devonian rocks are comparatively poor in *Ostracoda*, all the known forms (leaving *Estheria* out of consideration) belonging to the genera *Entomis*, *Leperditia*, and *Beyrichia*. In the Carboniferous

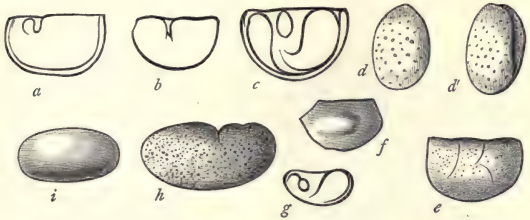


Fig. 100.—Fossil Ostracode Crustaceans:—*a Primitia strangulata*, Lower Silurian; *b Primitia Logani*, Lower Silurian; *c Beyrichia Klœdeni*, Upper Silurian; *d d' Cytherella inflata*, Carboniferous; *e Leperditia Anna*, Lower Silurian; *f Leperditia Canadensis*, Lower Silurian; *g Beyrichia impendens*, Upper Silurian; *h Beyrichia subarcuata*, Carboniferous; *i Candona Tateana*, Carboniferous. All enlarged.

Rocks no less than fifteen genera have been detected. Of these the genera *Leperditia*, *Bairdia*, *Beyrichia*, *Cythere*, *Cypridina*, *Cypridella*, and *Entomis* are the most important. The *Leperditiæ* were formerly referred to the genus *Cypris*, the species of which are exclusively fresh-water in their habits. It is noticeable, however, that some of the Carboniferous species have been referred, apparently on good grounds, to the recent genus *Candona*, all the forms of which inhabit fresh water. It is also noticeable that the genera *Beyrichia* and *Entomis* appear to die out in the Carboniferous Rocks, and have not been detected in any later formations. In the Permian Rocks we have only the genera *Bairdia*, *Cythere*, and *Cypridina*, of which the two former are represented by living forms. In the Secondary and Tertiary deposits, remains of Ostracode Crustaceans are abundant, often occurring in myriads in certain strata, to which they sometimes impart a fissile character. The chief genera which are represented in Mesozoic and Kainozoic time, are *Cypris*, *Candona*, *Bairdia*, *Cythere*, *Cytherella*, and *Cypridina*, all of which are represented by living species at the present day.*

* The facts here summarised are mainly drawn from the Memoirs of Professor Rupert Jones, and his admirable Monographs on the Ostracoda, published by the Palæontographical Society.

ESTHERIA.—Before going on to the order *Phyllopoda*, we may briefly notice here the little fossils belonging to the genus *Estheria*, as these are in some respects closely allied to the *Ostracoda*, or are intermediate between these and the true Phyllopods. Upon the whole, however, *Estheria* would seem to be most nearly allied to the living *Limnadia*, in which case it would be rightly referred to the *Phyllopoda*. The body in *Estheria* is enclosed in a bivalve carapace (fig. 101, A), and

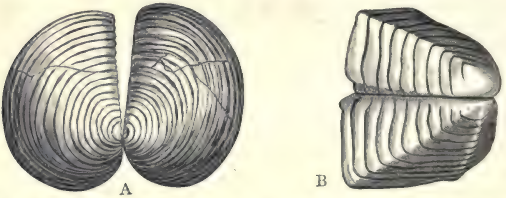


Fig. 101.—A, carapace of *Estheria ovata*, magnified six diameters, Trias; B, carapace of *Leaia Leidyi*, magnified five diameters, Lower Carboniferous (after Rupert Jones).

the feet are foliaceous. The valves of the carapace have a well-marked beak or "umbo," and are hinged to one another along a dorsal line. From these circumstances, and from their being marked with numerous concentric lines of growth, the carapace valves of *Estheria* very closely resemble the shells of certain Bivalve Molluscs, for which they have often been mistaken. The valves are usually sub-triangular, ovate, or subquadrate in form, and they possess a horny texture.

The living *Estheriæ* are, without exception, inhabitants of fresh or, rarely, brackish water; and no one of the recent twenty-four species has been detected in the sea. This would afford a strong presumption that the deposits in which fossil *Estheriæ* occur were deposited in fresh or brackish water; but they not uncommonly occur in conjunction with undoubted marine remains. They appear, on the whole, to occur most frequently in those accumulations that "have been decidedly the result of brackish-water inundations, and of more permanent lagoons" (Jones). Fossil *Estheriæ* occur in the Devonian, Carboniferous, Permian, Triassic, Jurassic, Cretaceous, and some Tertiary deposits; but they appear to have attained their maximum development towards the close of the Triassic period.

The genus *Leaia* (fig. 101) is very nearly allied to *Estheria*,

and comprises small Bivalved Crustaceans, with "dark, horny, sub-quadrate valves, obliquely ridged from umbo to angles, and ornamented with distinct lines of growth parallel with the border" (Jones). *Leaia* is a very widely distributed genus, but all the known species belong to either the Carboniferous or Permian Rocks.

ORDER PHYLLOPODA.

Crustacea, mostly of small size, the carapace protecting the head and thorax, or the body entirely naked. Feet numerous, never less than eight pairs, mostly foliaceous or leaflike, branchial in function.

Most of the living Phyllopods are inhabitants of fresh waters, but some live in the sea (*Nebalia*), and others affect waters which are abnormally salt (*Artemia*). The two most interesting recent forms, as bearing on fossil examples of the order, are *Limnadia* and *Apus*, both of which live in fresh water. In *Limnadia* the body is enclosed in an oval bivalve carapace, and there are from eighteen to thirty pairs of membranous leaf-like feet. In *Apus* the carapace is clypeiform, and protects a considerable portion of the abdomen; and there are sixty pairs of feet, of which all but the first pair are foliaceous.

Leaving out of sight the genera *Estheria* and *Leaia*, the Phyllopods are almost exclusively palæozoic in their distribution, and are chiefly, though not exclusively, known by their carapace-valves. The best known genera are the *Hymenocaris* of the Lingula flags, the *Caryocaris* of the Skiddaw slates, the *Peltocaris* and *Discinocaris* of the Lower Silurian, the *Ceratiocaris* of the Upper Silurian, and the *Dithyrocaris* of the Carboniferous Limestone. These forms have a general resemblance to one another, and are believed to be most nearly allied to the recent *Apus*, whilst they are exclusively palæozoic. The genus *Aspidocaris*, however, is allied to the preceding, and is found in the Triassic period.

In *Hymenocaris* (fig. 102, *b*) the carapace is comparatively large, sub-triangular, apparently not bivalved; there are nine free abdominal segments, and the last carries three pairs of unequal lanceolate appendages. In *Caryocaris* the carapace is bivalved, pod-shaped, and truncated behind, and the last abdominal segment carries three spines. In *Peltocaris* and *Discinocaris* (fig. 102, *c*.) the carapace is rounded, with concentric lines of growth, a dorsal furrow being present in the former, but wanting in the latter. In both there is commonly a wedge-shaped indentation in front, caused by the separation from the carapace of the anterior portion of the head. In *Ceratiocaris*,

again, the carapace appears to be bent, but not divided or hinged, along the dorsal line, and its shape is pod-like (fig. 102, *a*), with an abrupt posterior truncation. The surface of the carapace is marked with "fine, obliquely longitudinal, imbricated striæ" (M'Coy).

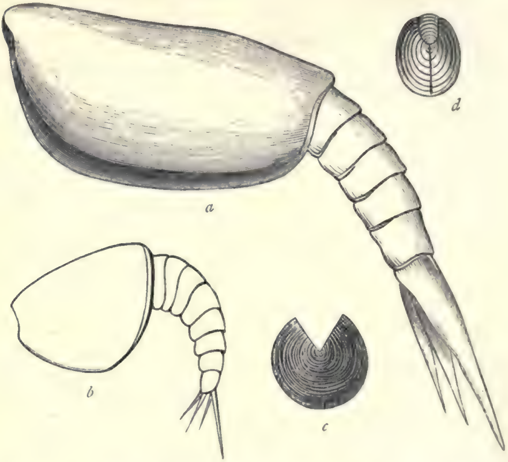


Fig. 102.—Palæozoic Phyllopods:—*a Ceratiocaris papilio*, Upper Silurian (Salter). *b Hymenocaris vermicauda*, Upper Cambrian (Salter). *c Discinocaris Browniana*, Lower Silurian (Original). *d Peltocaris aptychoides*, Lower Silurian (Woodward).

Order Trilobita.

Crustaceans in which the body is usually more or less distinctly trilobed; there is a cephalic shield, usually bearing a pair of sessile compound eyes; the thoracic somites are movable upon one another, and are very variable in number; the abdominal segments are coalescent, and form a caudal shield; there is a well-developed upper lip or "hypostome."

As regards the general structure of the Trilobites, the body was protected by a well-developed chitinous shell or "crust," which covered the whole dorsal surface of the body, and on which no appendages have ever been discovered except the eyes. The under surface of the body must, in many genera at

any rate, have been flexible and membranous; since many species have the power of rolling themselves up into a ball like the recent wood-lice (*Oniscus*). Other Trilobites, however, never seem to have possessed any power of rolling up. The dorsal crust usually exhibits more or less markedly a division into three longitudinal lobes (fig. 103), from which the name

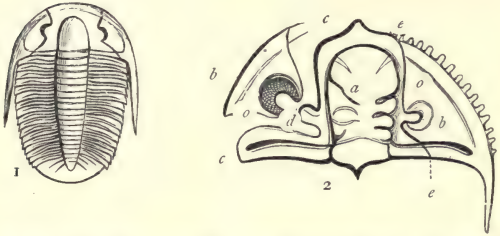


Fig. 103.—Morphology of Trilobites. 1. *Angelina Sedgwickii,* Upper Cambrian. 2. Diagram of a Trilobite (after Salter): *a* Glabella with its furrows; *b b* Free cheeks, bearing the eyes (*o o*); *c c* Fixed cheek, including the eye-lobe (*d*); *e e* Facial suture.

of the order is derived. In some cases, however, as in the genera *Homalonotus* and *Illænus*, this trilobation is only obscurely marked. The crust exhibits a well-marked division into three regions, which are commonly found detached and separate from one another. These three regions are—1, a cephalic shield; 2, a variable number of movable "body-rings" or thoracic segments; and 3, a caudal shield or "pygidium."

The cephalic shield or buckler (figs. 103—107) is generally more or less semicircular in shape, and is composed of a central and two lateral pieces, of which the two latter may or may not be united in front of the former. The central portion of the cephalic shield is usually elevated above the remainder. It is termed the "glabella," and it protected the region of the stomach. The form of the glabella varies a good deal. Usually it is widest in front (fig. 105), but its width may be nearly uniform (fig. 106), or it may be widest posteriorly, and contracted in front, as in *Calymene* (fig. 107). The glabella is bounded at the sides by two grooves, which are known as the "axal furrows," and is marked off behind by a third groove, which is termed the "neck-furrow." The surface of the glabella may be quite smooth, but it is ordinarily divided into lobes by grooves, which originate in the axal furrows, and pass inwards towards the middle line (fig. 103, 2). These

furrows mark the position of the segments which compose the glabella, and they are sometimes continuous from side to side. Usually there are three pairs of these furrows, a lower or basal, a middle or ocular, and an upper or frontal furrow; but there may be an additional pair of furrows in front of these. In some cases, as in *Illænus* (fig. 109), the glabella is very indistinctly marked off from the rest of the shield.

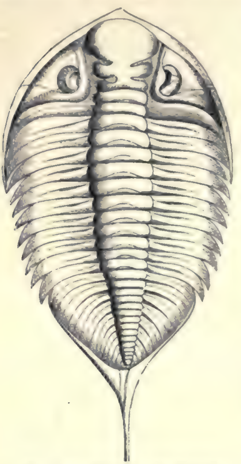


Fig. 104.—*Phacops* (*Dalmanites*) *limulurus*, Upper Silurian.

At each side of the glabella, and continuous with it, is a small semicircular area, which is termed the "fixed cheek" (fig. 103, 2). The glabella, with the "fixed cheeks," is separated from the lateral portions of the cephalic shield, termed the "movable" or "free cheeks," by a peculiar suture or line of division, which is known as the "facial suture" (fig. 103, 2, *e e*). No such peculiar line of division is known to exist in any recent Crustacean; but there is a faint indication of it in *Limulus*, and some doubtful traces of it in certain other forms. The course taken by the facial sutures differs in different cases, and causes an important difference in the structure of the cephalic shield. In some cases, the facial sutures, starting from the posterior margins of the buckler, skirt the fixed cheeks, and join one another in front of the glabella. In these cases it is obvious that the free cheeks form a single piece, so that the entire shield consists of but two portions—1, the glabella and fixed cheeks; and 2, the amalgamated free cheeks. In other cases, the facial sutures, instead of joining in front of the glabella, are continued forward, till they cut the anterior margin of the shield separately. In these cases the free cheeks are discontinuous, and the cephalic shield consists of three portions. In a few genera (as in *Trinucleus*, *Microdiscus*, and *Agnostus*), the facial suture is absent.

The posterior angles of the free cheeks are very commonly prolonged into longer or shorter spines, and they bear the eyes. The eyes are compound, and consist of an aggregation

of facets, covered by a thin cornea. They are generally crescentic or reniform in shape, and are invariably *sessile*, in the sense that they are never supported upon movable stalks. In some cases, however, they are carried upon longer or shorter prominences. The eyes differ much in size, and they are wanting in a few forms, such as the little *Agnosti.*

Fig. 105.—*Bronteus lunatus.*

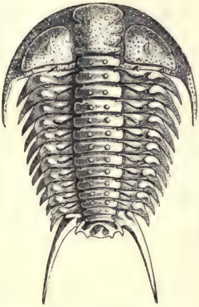


Fig. 106.—*Cheirurus pleurexanthemus.*

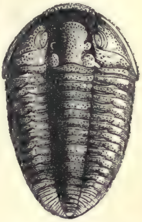


Fig. 107.—*Calymene Blumenbachii.*

Behind the cephalic shield comes the thorax, composed of a variable number of segments which are not soldered together, but are capable of more or less movement upon each other. The amount of movement thus allowed varies, but in several genera (*e.g.*, *Calymene* and *Illænus*) it was sufficiently great to allow of the animal completely rolling itself up after the manner of a hedgehog. The number of body-rings or segments in the thorax varies from no more than two (*Agnostus*), to as many as twenty-six (*Harpes ungula*). Ordinarily the thorax (fig. 108) is strongly trilobed, and each body-ring exhibits the same trilobation, being composed of a central, more or less convex portion, called the "axis," and of two flatter side-lobes, termed the "pleuræ." The pleuræ are in one piece with the axis, but are separated from it by a more or less pronounced groove, the "axal furrow." Each pleura is grooved longitudinally by a deep sulcus, and in many genera the ends of the pleuræ are furnished with facets, which have smooth surfaces, and slide under the preceding pleura, in the act of rolling up. In some genera, as in *Illænus* (fig. 109), the axis is very broad, the axal furrows are not marked, and the trilo-

bation of the thorax becomes very indistinct. This is likewise the case, but to a less extent, in the genus *Homalonotus*.

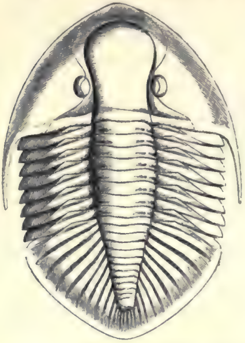


Fig. 108.—*Asaphus Canadensis* (Chapman), Lower Silurian.

Fig. 109.—*Illænus Barriensis* (Murchison), Lower Silurian.

The caudal shield or "pygidium"—commonly called the "tail"—is composed of a greater or less number of segments anchylosed or amalgamated. Commonly, the pygidium is tri-

Fig. 110.—Glabella and pygidium of *Dikelocephalus magnificus*, Quebec Group (Upper Cambrian). After Billings.

lobed (fig. 110), like the thorax, and consists of a central elevated "axis" and of a marginal "limb." The limb is

separated from the axis by axal furrows, and usually exhibits on its surface the lines which indicate the component pleuræ, as well as the longitudinal furrows on the faces of these. The extremity of the pygidium is sometimes simply rounded; but it may be prolonged into a shorter or longer spine or "mucro," and the ends of the pleuræ may also be extended into spine-like projections (fig. 110).

Until recently, the only structure which had been discovered on the under surface of any Trilobite was a broad plate situated in front of the mouth, and doubtless corresponding with the upper lip—" labrum " or " hypostome "—of living Crustaceans (fig. 111). The form of this hypostome very closely resembles that of the lip-plate of the recent *Apus*, one of the Phyllopods. Quite recently, Mr Henry Woodward has described a specimen of *Asaphus platycephalus*, in which, in addition to the lip-plate, there is a jointed filament (fig. 111, *p*), apparently springing from a maxilla, and being the remains of a maxillary "palpus." Mr Woodward, who is one of the highest living authorities upon the *Crustacea*, concludes that there is no reason to doubt that Trilobites possessed antennæ and antennules, mandibles, and maxillæ, and foot-jaws; though, with the exception of the above, no traces of these organs have ever been detected.

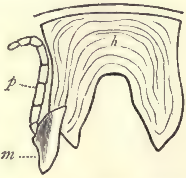


Fig. 111. — Buccal organs of *Asaphus platycephalus*. After Woodward. *h* Hypostome; *p* Palpus; *m* Maxilla (?)

Also recently, a specimen of the large Trilobite, *Asaphus platycephalus* (fig. 112), has been described by Mr Billings as possessing organs which this distinguished palæontologist regards as being the remains of legs. The structures in question are in the form of eight pairs of apparently jointed appendages, which correspond with the eight segments of the thorax, arising near the middle line, and curving forwards. Mr Henry Woodward corroborates the view propounded by Mr Billings, that these structures are of the nature of ambulatory legs. Professors Dana and Verrill, on the other hand, regard these remains as being "the semi-calcified arches in the membrane of the ventral surface, to which the foliaceous appendages or legs were attached."

Whichever view be adopted as to the nature of this specimen, it seems tolerably certain that *most* Trilobites cannot have possessed limbs which were furnished with a chitinous exoskeleton, and were thus capable of being preserved in a fossil

condition. The great abundance of Trilobites as fossils, and their excellent preservation, as a general rule, render it probable that the limbs of most were of a soft and fleshy nature.

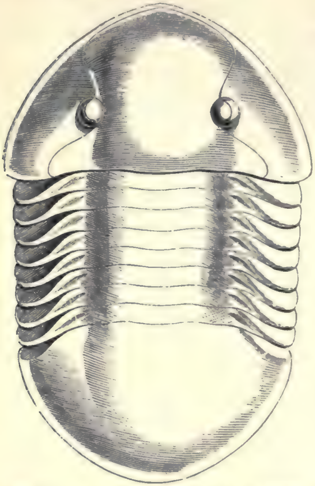


Fig. 112.—*Asaphus platycephalus*, Lower Silurian.

At the same time it is very possible that *some* forms were possessed of chitinous jointed limbs, as great variations exist in the character of the appendages even within the limits of a single order. The general view which has up to the time of this discovery been held is, that the body of the Trilobite occupied the median lobe of the crust, commencing with the glabella in front, and terminating with the pygidium behind, whilst the axial lobes protected a series of delicate, membranous respiratory feet. It is supposed, however, by Mr Woodward, that the branchiæ were borne on the under surface of the caudal shield.

As regards the systematic position of the Trilobites, they have very generally been placed in the neighbourhood of the *Phyllopoda*, or of the much higher order of the *Isopoda*. They have been placed near the Phyllopods chiefly from the possession of numerous (not definite) body-rings, from the resemblance of their hypostome to the lip-plate of the Phyllopodous genus *Apus*, and from their supposed possession of membranous gill-feet. The recent discoveries, however, of Messrs Billings and Woodward would lead to the belief that the Trilobites, if not actually belonging to the *Isopoda*, have at any rate closer affinities with this order than with any other. They agree with the Isopods in the possession of sessile compound eyes, in having the abdominal somites coalescent, and in sometimes possessing the power of rolling themselves up into a ball. They differ, however, from the Isopods in the very important character that the thoracic segments of the latter are

always definite and are almost invariably *seven* in number. In the meanwhile, therefore, it is safest to regard the *Trilobita* as a peculiar order, the exact position of which in the Crustacean class is still undetermined.

The general facts as to the distribution of the *Trilobita* in past time are soon told. The Trilobites are exclusively Palæozoic, their range extending from the Upper Cambrian to the Lower Carboniferous. If the *Palæopyge Ramsayi* of the Longmynd beds be a Trilobite, then the order has its commencement in the Lower Cambrian. In the Upper Cambrian Rocks, and especially in the strata which constitute the "Menevian Group" of Salter, and the "Primordial Zone" of Barrande, is a peculiar group of forms commonly spoken of as the "Primordial Trilobites." These belong mostly to the two families *Agnostidæ* and *Olenidæ*, and to the genera *Agnostus*, *Paradoxides*, *Olenus*, *Dikelocephalus*, *Conocoryphe*, *Angelina*, *Ellipsocephalus*, &c.

Many of these forms are distinguished by degraded characters, such as the absence of eyes, the want of the facial suture, the segmentation of the glabella, or the multiplication or diminution of the number of body-rings. It should not be omitted to be noticed that the singular tracks which have been described from the Potsdam Sandstone (Upper Cambrian) of Canada, under the names of *Protichnites* and *Climactichnites*, are believed with good reason to be the tracks of Trilobites. In the Lower and Upper Silurian Rocks the Trilobites attain their maximum of development, the leading families being the *Asaphidæ*, *Phacopidæ*, *Trinucleidæ*, *Cheiruridæ*, and *Calymenidæ*, and the chief genera being *Asaphus*, *Ogygia*, *Phacops*, *Trinucleus*, *Ampyx*, *Cheirurus*, *Encrinurus*, *Calymene*, and *Homalonotus*. In the Devonian Rocks, again, Trilobites are tolerably abundant, though less so than in the preceding series. The commonest Devonian genera are *Phacops*, *Homalonotus*, and *Bronteus*. Lastly, the order seems to die out before the close of the Carboniferous period, being represented in the Carboniferous Limestone solely by the three genera, *Phillipsia*, *Brachymetopus*, and *Griffithides*.

The following gives the leading characters of the more important families of Trilobites, with a few of the chief genera in each family, and the range of the group in time:—

1. AGNOSTIDÆ.—Characterised by their small size, the head and tail being covered by nearly equal and similar shields, and the reduction of the body-rings to two in number (fig. 113). There are no eyes, and the facial suture is wanting. The family includes only one well-marked genus, viz. *Agnostus*,

which ranges from the Upper Cambrian to near the summit of the Lower Silurian Rocks.

Fig. 113.—*Agnostus princeps*, Upper Cambrian. After Salter.

2. Olenidæ or Paradoxidæ.—Characterised by having long bodies, with numerous free thoracic segments (from eight to twenty-three in number). The caudal shield is small, and generally consists of very few segments. The pleuræ are mostly prolonged into longer or shorter spines, which are directed backwards. The family includes some of the largest of the Trilobites, and is mainly characteristic of the "Primordial Zone" (Upper Cambrian). It occurs, however, in the lower

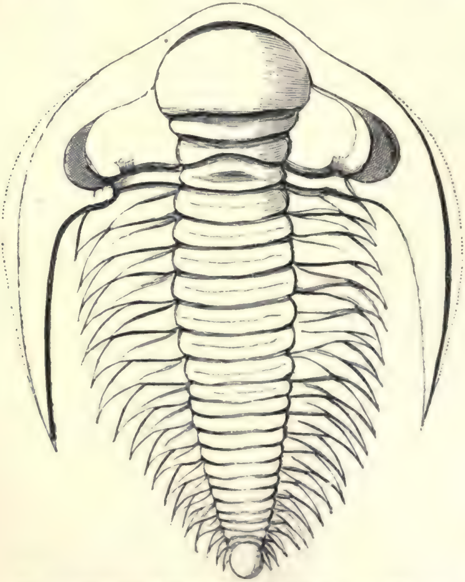


Fig. 114.—*Paradoxides Micmac* (?), Upper Cambrian. After Dawson.

Silurian, but appears to die out in the Caradoc period. The

chief genera are *Olenus*, *Paradoxides*, *Dikelocephalus*, *Conocoryphe*, *Sao*, *Angelina*, and *Ellipsocephalus*.

3. Asaphidæ.—Large Trilobites, generally oval, and never furnished with spines or tubercles on their surface. The eyes smooth, and the facial sutures terminating on the posterior margin. The cephalic and caudal shields generally of large size, the glabella of the former often obscure, and the latter sometimes exhibiting no indication of its component segments. The body-rings usually eight in number, sometimes more, rarely fewer (six in *Æglina*).

The family *Asaphidæ* is characteristically Lower Silurian in its distribution, commencing by a few forms in the Upper Cambrian, and being hardly at all represented in Upper Silurian strata. The most important genera are *Asaphus*, *Ogygia*, *Illænus*, *Æglina*, *Barrandia*, and *Psilocephalus*.

4. Trinucleidæ.—Cephalic shield large, the posterior angles of the cheeks prolonged into long spines. Body-rings six (sometimes five ?) in number. Facial suture sometimes absent

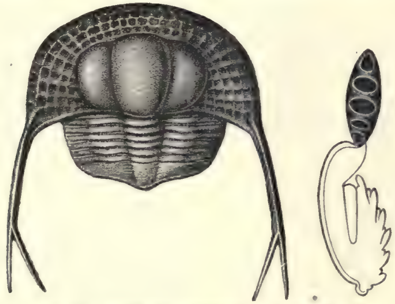


Fig. 115.—*Trinucleus Pongerardi*, Lower Silurian.

(*Trinucleus*); eyes sometimes wanting (*Ampyx*). The *Trinucleidæ* are exclusively Lower Silurian, though there are traces of their existence in the higher portion of the Upper Cambrian. The only genera referred to this family are *Trinucleus*, *Ampyx*, and *Dionide*.

5. Cheiruridæ.—Cephalic shield with the facial sutures terminating on its exterior margins. Body-rings eleven. Pleuræ with free extremities. Caudal shield of few segments, the ends of these being free. The family extends from the Upper Cambrian to the Devonian, but it attains its greatest

development in the Silurian period. The chief genera are *Cheirurus*, *Amphion*, *Sphærexochus*, *Staurocephalus*, *Deiphon*, *Encrinurus*, and *Cybele*.

6. CALYMENIDÆ.—Crust granulated, often tuberculated. Body-rings thirteen in number. Facial sutures ending at the posterior angles of the cephalic shield. Body sometimes very indistinctly trilobed (*Homalonotus*). The family appears to commence at the base of the Lower Silurian series or at the summit of the Upper Cambrian, and ranges into the Devonian. The only genera are *Calymene* and *Homalonotus*, of which the former is markedly trilobed, but the latter very indistinctly so (fig. 116). The best-known species are *Calymene Blumenbachii*, which ranges from the Caradoc (Lower Silurian) to the Ludlow Rocks (Upper Silurian), and *Homalonotus delphinocephalus*, which is a well-known Upper Silurian Trilobite.

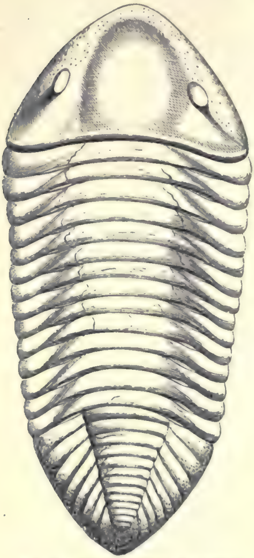


Fig. 116.—*Homalonotus delphinocephalus*, Upper Silurian.

7. PHACOPIDÆ.— "Eyes largely faceted, the cornea convex over each facet, forming a granulated, not a smooth eye. Facial suture ending posteriorly on the outer margin of the cheek. Thorax with eleven rings" (Salter). This family includes the single genus, *Phacops*, divided into the sub-genera *Trimerocephalus*, *Phacops*, *Acaste*, *Chasmops*, *Dalmania*, and *Cryphæus*. The family *Phacopidæ* ranges from the base of the Lower Silurian series (perhaps from the Upper Cambrian) to the summit of the Devonian series. Amongst the Upper Silurian species may be mentioned *Phacops caudatus* and *P. Downingiæ*, as well-known fossils; whilst *P. latifrons* is a familiar and widely-distributed Devonian species.

8. LICHADÆ.—Cephalic shield small, the facial sutures cutting its outer margins. Glabella large, deeply furrowed.

Body-rings eleven in number. Pygidium with an undefined axis and broad limb. The family includes the single genus *Lichas*, and extends from the Lower Silurian into the Devonian.

9. PROETIDÆ.—Cephalic shield with the facial sutures not uniting in front of the glabella. Body-rings nine or ten in number. Axis elongated. This family ranges from the Lower Silurian to the Carboniferous. Besides *Proetus*, this family includes *Phillipsia* and *Griffithides*.

10. ACIDASPIDÆ.—Surface ornamented. Body-rings from eight to ten in number. The ends of the pleuræ extended into spines, and directed backwards. Pygidium of from two to three segments, small, furnished with prominent spines. The genus *Acidaspis* ranges from the Lower Silurian into the Devonian.

11. BRONTEIDÆ.—Body-rings ten in number. Pygidium large, the axis extremely short, the margin entire. The family includes only the genus *Bronteus* (fig. 105), and is confined to the Upper Silurian and Devonian Rocks.

12. HARPEDIDÆ. — Cephalic shield horse-shoe-shaped, its lateral angles greatly prolonged. Facial suture cutting the exterior margin of the buckler. Body-rings numerous, sometimes no less than twenty-six in number. Pygidium small. This family comprises only the genus *Harpes*, all the species of which belong to the Lower Silurian, Upper Silurian, and Devonian.

13. CYPHASPIDÆ.—Cephalic shield with the posterior angles usually prolonged into spines, the facial suture cutting its exterior margins. Body-rings from ten to twenty-two. Crust spinulose or pitted. The chief genera of this family are *Cyphaspis* and *Aulacopleura* (*Arethusina*), the former ranging from the Lower Silurian to the Devonian, the latter exclusively confined to the Silurian series.

ORDER MEROSTOMATA.

Crustaceans, often of large size, in which the mouth is furnished with mandibles and maxillæ, the terminations of which become walking or swimming feet, or organs of prehension (figs. 117, 118).

The order *Merostomata* comprises the two sub-orders of the *Xiphosura* and *Eurypterida*. The former appears to have commenced its existence in the Upper Silurian period, and is represented at the present day by the *Limuli* or King-crabs. The latter is wholly extinct, and is exclusively Palæozoic, none

of its members being known out of the Silurian, Devonian, and Carboniferous formations.

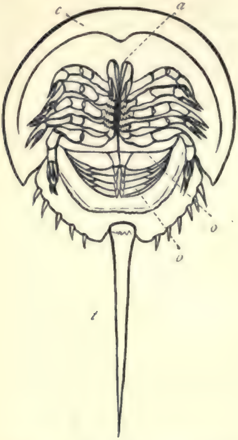


Fig. 117.—Xiphosura. *Limulus polyphemus*, viewed from below. *c* The cephalic shield carrying the sessile eyes upon its upper surface; *o* "Operculum," covering the reproductive organs; *b* Branchial plates; *a* First pair of antennæ (antennules) ending in chelæ. Below these is the aperture of the mouth surrounded by the spiny bases of the remaining five pairs of appendages, which are regarded by Woodward as being respectively, from before backwards, the great antennæ, the mandibles, the first maxillæ, the second maxillæ, and a pair of maxillipedes. All have their extremities chelate.

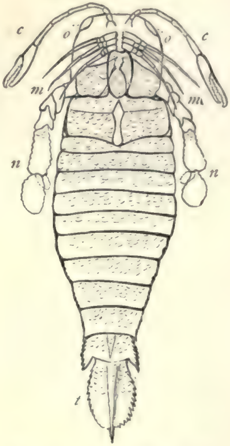


Fig. 118. — Eurypterida. *Pterygotus Anglicus*, restored (after H. Woodward). *c c* Chelate antennæ; *o o* Eyes, situated at the anterior margin of the carapace; *m m* The mandibles, and the first and second maxillæ; *n n* The maxillipedes; the basal margins of these are serrated, and are drawn as if seen through the metastoma or post-oral plate, which serves as a lower lip. Immediately behind this is seen the operculum or thoracic plate, which covers the two anterior thoracic somites. Behind this are five thoracic and five abdominal somites, and lastly, there is the telson (*t*).

SUB-ORDER I.—EURYPTERIDA.

"*Crustacea with numerous, free, thoracico-abdominal segments, the first and second (?) of which bear one or more broad lamellar appendages upon their ventral surface, the remaining segments being devoid of appendages; anterior rings united into a carapace, bearing a pair of larval eyes (ocelli) near the centre, and a pair of large, marginal, or sub-central eyes; the mouth furnished with a broad post-oral plate, or metastoma, and five pairs of movable*

appendages, the posterior of which form great swimming-feet; the telson, or terminal segment, extremely variable in form; the integument characteristically sculptured."—(Henry Woodward.)

In the typical *Eurypterids*, such as *Pterygotus* (fig. 118) and *Eurypterus*, the anterior portion of the body is covered by a buckler or carapace, which bears a pair of minute larval eyes, and a pair of large compound eyes placed marginally or subcentrally. On the under surface of the carapace are five pairs of appendages. The first pair of these is usually regarded as representing the antennæ. The appendages of this pair are mostly chelate, or converted into nipping-claws, but they are sometimes simple, and they sometimes are spinous towards their bases, and officiate as masticatory organs (*Eurypterus* and *Slimonia*). The next three pairs of appendages are simply pointed spinous organs ("pedipalps"), but the last pair is sometimes converted into rowing-organs (*Stylonurus*). The last pair of appendages constitute two greatly-developed swimming-feet, the bases of which are furnished with spines, and form powerful jaws. The bases of these jaw-feet are covered by a greatly-developed post-oral plate or "metastoma." Behind the head come thirteen free segments, counting the telson as one. The first two of these, immediately behind the carapace, are covered below by a thoracic plate or "operculum," which doubtless protected the reproductive organs. The other somites carry no appendages, though it is probable that some of them bore membranous branchiæ. The "telson" or terminal segment of the abdomen (fig. 118, *t*), is sometimes lanceolate or bilobate, as in *Pterygotus* and *Slimonia*, or sometimes narrow and sword-shaped, as in *Eurypterus* and *Stylonurus*. The surface of the crust is sculptured over the greater part of its extent, with characteristic markings, which look something like the scales of an ordinary Bony fish. These "scale-marks," however, are often wanting over parts of the surface.

The *Eurypterids* range from the Upper Silurian, where they attain their maximum, through the Devonian, into the Carboniferous Rocks, where they appear to die out. Traces, however, of these large Crustaceans are by no means wanting in the Lower Silurian, though as yet undescribed. Of the typical genera, *Pterygotus* extends from the Upper Silurian to the Upper Devonian, and species of this genus seem to have attained a gigantic size. (*Pterygotus Anglicus* is calculated to have reached a length of six feet.) *Slimonia* is Upper Silurian, and *Stylonurus* is both Upper Silurian and Devonian. *Eurypterus* is not known in the Silurian, but is represented by many

species in the Devonian, and extends into the Carboniferous Rocks. *Hemiaspis*, with only nine segments and the telson behind the carapace, is exclusively Upper Silurian. Lastly, *Pseudoniscus*, with the same number of free segments, is found in the passage-beds between the Upper Silurian and Devonian. In conclusion, it is interesting to note that these ancient Crustaceans present many larval features, resembling the larvæ of the *Decapoda*, especially in the fact that the hinder portion of the body is composed of free segments, which carry no appendages.*

SUB-ORDER II.—XIPHOSURA (*Pœcilopoda*).

"*Crustacea having the anterior segments welded together to form a broad convex buckler, upon the dorsal surface of which are placed the compound eyes and ocelli; the former sub-centrally, the latter in the centre in front. The mouth is furnished with a small labrum, a rudimentary metastoma, and six pairs of appendages. Posterior segments of the body more or less free, and bearing upon their ventral surfaces a series of broad lamellar appendages; the telson, or terminal segment, ensiform.*"—(Henry Woodward.)

The only living members of the *Xiphosura* are the *Limuli*, commonly known as King-crabs or Horse-shoe Crabs. The anterior portion of the body is covered by a broad horse-shoe-shaped buckler (fig. 117), the upper surface of which bears a pair of larval and a pair of compound eyes. On the lower surface of the carapace is placed the aperture of the mouth, surrounded by six pairs of limbs, the bases of which are spinous, and officiate as jaws, whilst their terminations are converted into chelæ or nipping-claws. The first pair of appendages is placed in front of the mouth, and represents the antennæ, so that the antennæ of the King-crabs are chelate. Behind the cephalic buckler comes a second shield, composed of six amalgamated segments, below which are carried the reproductive organs and branchiæ, the former protected by a thoracic plate or "operculum," the latter borne by five pairs of lamellar appendages. Lastly, articulated to the posterior margin of the abdominal shield, is a long sword-like spine or "telson" (fig. 117, *t*).

The *Xiphosura* seem to have commenced existence in the Upper Silurian period, where they are represented by the *Neolimulus falcatus* of Mr Henry Woodward. With this ex-

* The student desirous of fuller information on this subject, as on the *Xiphosura* also, should consult the excellent memoirs by Mr Henry Woodward, and especially his monograph of the Merostomata, published by the Palæontographical Society.

ception, however, no Limuloid Crustaceans are known till the Carboniferous Rocks are reached. Here we have the two genera *Prestwichia* and *Belinurus*, the former represented by two, the latter by four species. In *Prestwichia* (fig. 119), the thoracic and abdominal segments are not separable from one another, and the former are anchylosed or amalgamated, as well as the latter. In *Belinurus* there are five thoracic and three abdominal segments (as in the preceding), but the thoracic somites are free and movable, whilst the abdominal ones are anchylosed. The only other genus of the *Xiphosura* is *Limulus* itself. This genus is represented by forms doubtfully here referable as early as the Permian Rocks. Another dubious form occurs in the Trias. Seven species have been described from the Lithographic slates of Solenhofen (Middle Oolites). One doubtful form occurs in the Chalk, a single Tertiary species has been described, and four species are known as existing at the present day.

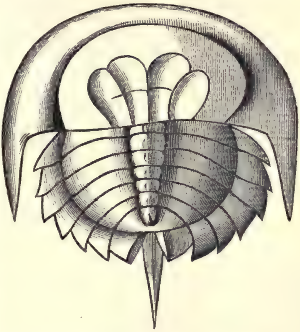


Fig. 119.—*Prestwichia* (*Limulus*) *rotundata*, Coal-Measures.

CHAPTER XVI.

CRUSTACEA—Concluded.

MALACOSTRACA.

THE Malacostracous Crustaceans are distinguished by the possession of a definite number of body-segments, seven somites generally going to make up the thorax, and an equal number entering into the composition of the abdomen (counting the telson as a somite). The *Malacostraca* are divided into two primary sections, termed respectively *Edriophthal-*

mata and *Podophthalmata*, according as the eyes are sessile or are supported upon eyestalks.

DIVISION A. EDRIOPHTHALMATA.—The division of the Sessile-eyed Crustaceans comprises those *Malacostraca* in which the eyes are not supported upon stalks or peduncles, and there is mostly no carapace. The eyes are sometimes compound, sometimes simple, and are placed on the sides of the head. The head is almost always distinct from the body; and there are typically seven pairs of feet in the adult. (Hence the name of *Tetradecapoda* applied to this division by Agassiz.) The *Edriophthalmata* include the orders *Læmodipoda*, *Amphipoda*, and *Isopoda*, of which the two latter are alone known in a fossil condition, whilst the last is the only one of any importance.

ORDER AMPHIPODA.

Small Crustaceans in which the respiratory organs have the form of membranous vesicles attached to the bases of the thoracic limbs. Abdomen well developed, and composed of seven segments. Seven pairs of thoracic limbs.

The most familiar recent forms of the *Amphipoda* are the "fresh-water Shrimps" (*Gammarus*), the Sand-hoppers (*Talitrus*), and the Shore-hoppers (*Orchestia*). The oldest representative of the order is a doubtful form, which has been described by Mr Woodward from the Upper Silurian Rocks under the name of *Necrogammarus*. The Carboniferous genus *Gampsonyx* has been referred here, but is more properly placed amongst the *Stomapoda*. There are no other fossil Amphipods of any importance.

ORDER ISOPODA.

Crustaceans in which the head is distinct from the segment bearing the first pair of feet. The eyes are compound and sessile. There are usually seven pairs of thoracic appendages, borne upon seven movable segments. The animal sometimes has the power of rolling into a ball. The abdominal segments are coalescent, and form a broad caudal shield, beneath which the branchiæ are carried.

Of the living Isopods, some (*Bopyridæ*) are parasitic in their adult condition upon other Crustaceans. Others, such as the common Wood-lice (*Oniscus*), live habitually upon the land. Others, again, are littoral in their habits, or frequent the sea.

The oldest known Isopod is a large form which has been described by Mr Henry Woodward from the Devonian Rocks

under the name of *Præarcturus.* It is believed to resemble the living *Arcturus Baffinsii.* From the Carboniferous Rocks an *Isopod* has been described under the name of *Acanthotelson.* In the Permian Rocks we have the genus *Prosoponiscus,* which, however, has been referred to the *Amphipoda.* In the Upper Oolites (Purbeck beds) occurs the *Archæoniscus Brodiei* (fig. 120), often in large numbers. In the Chalk occurs the genus *Palæga,* which ranges to the Miocene Tertiary. Lastly, several forms, some of which are of very uncertain affinities, have been described from the Tertiary Rocks.

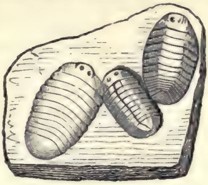


Fig. 120.—*Archæoniscus Brodiei.* A fossil Isopod, from the Upper Oolites.

DIVISION B. PODOPHTHALMATA. — The members of this division are Malacostracous Crustaceans, in which the eyes are compound, and are supported upon movable stalks or peduncles, and the anterior portion of the body (cephalothorax) is protected by a carapace. In this division are included the two orders of the *Stomapoda* and *Decapoda.*

ORDER STOMAPODA.

Stalk-eyed Crustaceans in which there are generally from six to eight pairs of legs, and the branchiæ are not enclosed in a cavity beneath the thorax, but are either suspended beneath the abdomen, or, more rarely, attached to the thoracic legs.

Of the living Stomapods the best-known forms are the Locust-shrimps (*Squilla*), the Glass-shrimps (*Erichthys*), and the Opossum-shrimps (*Mysis*). The earliest-known example of the *Stomapoda* is the *Gampsonyx fimbriatus* of the Carboniferous Rocks; and the *Pygocephalus Couperi* of the same formation is also probably to be referred to this order. The genus *Squilla* itself does not appear to be represented in rocks older than the Eocene Tertiary.

ORDER DECAPODA.

Crustaceans with five pairs of ambulatory legs, of which the first pair is modified to form nipping-claws, some of the other pairs behind this being often chelate as well. There is a large cephalothoracic carapace, and the branchiæ are contained in cavities at the sides of the thorax.

The order *Decapoda* includes the highest forms of the entire class of the Crustaceans, such as the Lobsters, Hermit-crabs, and Crabs, and it is divided into the following three tribes:—

TRIBE I. MACRURA.—The members of this tribe, such as the Lobsters, Shrimps, Prawns, and Cray-fish, have a long and well-developed abdomen, the posterior extremity of which forms a powerful natatory organ or caudal fin. This is constituted by a greatly-expanded pair of natatory appendages ("swimmerets") borne upon the last segment but one of the abdomen, between which is placed the last segment or "telson."

The *Macrurous* Decapods are unquestionably of a lower type than the *Brachyurous* Decapods or Crabs; so that it is no matter of surprise to find that the former, so far as is known, have enjoyed a vastly higher antiquity than the latter. The *Brachyura* are not known in deposits older than the Oolites. The *Macrura*, on the other hand, were in existence before the close of the Palæozoic period. In the Carboniferous formation we have several forms of Prawn-like Crustaceans belonging to the genus *Anthrapalæmon* (or *Anthracopalæmon*), of which a species is figured below (fig. 121). In

Fig. 121.—*Anthrapalæmon Salteri*, Carboniferous. (After Salter.)

the Permian Rocks no Macrurous Decapods are known to occur. In the Trias, examples of the genera *Galatea* and *Litogaster* have been detected, and other forms have been alleged to occur. In the Jurassic and Cretaceous strata "Long-tailed" Decapods are extremely abundant, and are often beautifully preserved. Amongst the more remarkable of the Jurassic genera may be mentioned *Eryon* (fig. 122),

which commences in the Lias, but attains its maximum in the Middle Oolitic strata, being especially abundant in the fine-grained Lithographic Slates of Solenhofen. In this singular genus, the carapace is large and broad, and nearly quadrate in figure, whilst the antennæ are very small. Another singular genus from the Solenhofen Slates is *Megachirus*, in which the first pair of legs is enormously elongated, but not terminated by chelæ. In the Cretaceous Rocks are numerous Macrourans, belonging to the genera *Meyeria*, *Enoploclytia*, *Hoploparia*, &c. In many parts of the Tertiary series, especially in the London Clay (Eocene), are numerous remains of *Macrura*, some of

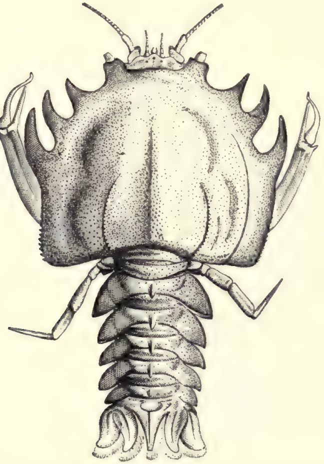


Fig. 122.—*Eryon arctiformis*, Middle Oolites (Solenhofen Slates).

which have been referred, with more or less doubt, to such living genera as *Astacus* and *Palinurus*.

TRIBE II. ANOMURA.—The Anomurous Decapods are distinguished by the condition of the abdomen, which is neither so well developed as in the *Macrura*, nor so rudimentary as in the *Brachyura*. The abdomen does not take any part in locomotion, and does not terminate posteriorly in a caudal fin. The penultimate segment of the abdomen, however, is mostly furnished with more or less well-developed appendages.

The best-known living *Anomura* are the Hermit-crabs or Soldier-crabs (*Paguridæ*), the Crab-lobsters (*Porcellanæ*), and the Sponge-crabs (*Dromia*).

The *Anomura* are of small importance as fossils. They commence in the Secondary period, a few forms having been described from the Oolites, and a greater number from the Cretaceous Rocks. In the Tertiary period Anomurous Crustaceans are not uncommon; and the genus *Pagurus* itself appears to be represented in the Red Crag (Pliocene). The *Dromilites* of the London Clay is supposed to be related to the living *Dromia*.

TRIBE III. BRACHYURA.—The "Short-tailed" Decapods or Crabs are distinguished by having a rudimentary abdomen, which is tucked up beneath the cephalothorax. The carapace is usually very large, and the extremity of the abdomen is not provided with any appendages. Most of the Crabs are littoral in their habits, and have legs formed for walking. Others are adapted for swimming, and the Land-crabs habitually live inland.

As before remarked, the Brachyurous Decapods are much later in their appearance than the *Macrura*. The oldest known Crab, at present, is the *Palæinachus longipes*, described by Mr Henry Woodward from the Forest Marble (Lower Oolites). In the Cretaceous series Crabs are tolerably abundant, one Cretaceous form belonging to the recent genus *Cancer*. In the Tertiary Rocks, and especially in the London Clay (Eocene), remains of Crabs occur in profusion. The chief Tertiary genera are *Xanthopsis*, *Xantholites*, *Cancer* (fig. 123), *Grapsus*, and *Ebalia*.

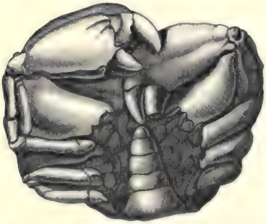


Fig. 123.—*Cancer* (*Carpilius*) *macrochelus*, Tertiary.

CHAPTER XVII.

ARACHNIDA, MYRIAPODA, AND INSECTA.

Class Arachnida.

The *Arachnida* are *Articulate animals, in which the respiratory organs, when present, are in the form of pulmonary chambers or sacs, or of ramified tubes ("tracheæ") formed by an involution of the integument and fitted for breathing air directly; or both these organs are combined. In no case are the breathing-organs in the form of gills. There are four pairs of locomotive limbs, and there are no limbs attached to the segments of the abdomen. There is only one pair of antennæ, and these are not present as antennæ, but are converted into jaws or pincers. The head is amalgamated with the thorax to form a cephalothorax, the eyes are sessile, and the integuments are more or less chitinous.*

The *Arachnida* are mainly distinguished from the *Crustacea** by the absence of gills, and the general presence of organs adapted for breathing air directly. They are distinguished from the Insects by the possession of four pairs of legs, by never possessing wings, and by having simple eyes, whilst the head is amalgamated with the thorax. From the Myriapods they are distinguished by the fact that the legs of the latter are

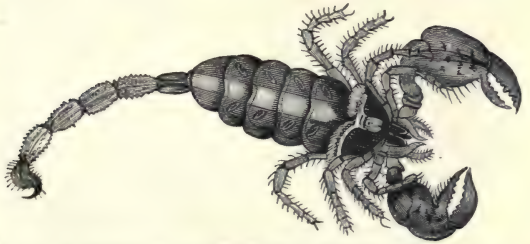


Fig. 124.—A recent Scorpion (reduced). The great nipping-claws of the Scorpion are not legs, but are a development of organs belonging to the mouth.

never less than nine pairs in number, whilst the segments of the thorax are distinct from one another and from the head,

* Van Beneden would refer the Trilobites, King-crabs, and Eurypterids to the *Arachnida*, but such a radical change must be supported by overwhelming evidence before it can be accepted.

and the segments of the abdomen carry legs. As is the case with all the air-breathing Articulates, the remains of *Arachnida*, though of considerable theoretical interest, are of very rare occurrence as fossils. They will therefore be very briefly noticed here. Of the groups of the *Arachnida*, the Mites (*Acarida*), the Harvest-spiders (*Phalangidæ*), the Book-scorpions (*Pseudoscorpionidæ*), the Scorpions (*Pedipalpi*), and the true Spiders (*Araneida*), have all been detected in a fossil condition. The three first groups require no consideration here, being almost unknown except as occurring in amber, which is a fossil resin of late Tertiary age. The Scorpions and Spiders both appear to have come into existence in the Carboniferous period, and the forms which then existed do not appear to have been strikingly different from living types.

Order Pedipalpi.—The typical members of this order are the Scorpions (*Scorpionidæ*), in which *the abdomen is distinctly*

Fig. 125.—*Cyclophthalmus senior.* A fossil Scorpion from the Coal-measures of Bohemia.

segmented, and not separated from the thorax by any marked constriction. The respiratory organs are in the form of pulmonary sacs opening on the under surface of the abdomen by distinct apertures or "stigmata." The jaws (maxillæ) carry an enor-

mously-developed pair of nipping-claws (fig. 124), and the antennæ are also converted into chelæ. The head carries six, eight, or twelve simple eyes, and the last joint of the abdomen (telson), terminates in a hooked claw, perforated for the transmission of the duct of a poison-gland.

As regards their distribution in time, the Scorpions commence in the Carboniferous period, where they are represented by the genera *Eoscorpius* and *Cyclophthalmus*. The most celebrated fossil Scorpion is the *Cyclophthalmus senior* (fig. 125) of the Bohemian Coal-measures. This remarkable form resembles the living *Androctonus* in having twelve eyes, but these are disposed in a circle, whereas in the latter there are six eyes on each side of the head.

ORDER ARANEIDA.—This order includes the true Spiders, which are characterised by the amalgamation of the head and thorax into a single mass, *to which the generally soft and unsegmented abdomen is attached by a constricted portion or peduncle.* Respiration is effected by pulmonary sacs in combination with air-tubes (tracheæ). The head bears from six to eight simple eyes.

The oldest-known Spiders occur in the Carboniferous Rocks. In the Coal-measures of Upper Silesia, Römer has described a Spider, which is allied to the living *Lycosa*, and which he has termed *Protolycosa anthracophila*. Other fossil Spiders have been described from the Lithographic Slates of Solenhofen (Middle Oolite), and from the Tertiary Rocks, and a good many species occur preserved in amber.

CLASS MYRIAPODA.

The Myriapods are *Articulate animals in which the head is distinct, and the remainder of the body is divided into nearly similar segments. There is no marked boundary-line between the thorax and abdomen, and the segments of the latter carry locomotive limbs. There is one pair of jointed antennæ, and the number of legs is always more than eight pairs. Respiration is effected by air-tubes (tracheæ).*

The living Myriapods are divided into the three orders *Chilopoda*, *Chilognatha*, and *Pauropoda*. In the *Chilopoda* are the Centipedes, characterised by their masticatory mouth, and carnivorous habits, by the possession of legs in single pairs (usually from fifteen to forty pairs), and by having antennæ of from fourteen to forty or more joints. In the *Chilognatha* are the Millipedes and Gallyworms, characterised by their vegetarian habits, by having the segments of the body so amal-

gamated that the legs appear to be arranged in double pairs, and by having antennæ of six or seven joints. In the *Pauropoda* is the single genus *Pauropus*, characterised by having only nine pairs of legs, and the antennæ bifid, with three long multi-articulate appendages.

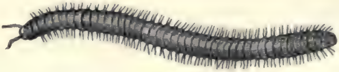


Fig. 126.—Millipede (*Iulus*).

The oldest-known Myriapods occur in the Coal-measures, the two best-known genera being *Xylobius* and *Archiulus*. These genera belong to the order *Chilognatha*, and comprise, therefore, vegetable-feeders. In *Xylobius* (fig. 127) the segments are divided by cross sutures into numerous fragments, in a manner wholly unknown amongst recent forms. Several species of this genus are known, of which the one figured above derives its specific name from the fact that it is found in the hollow trunks of *Sigillaria*. It must have possessed, like the living Gallyworms, the power of rolling itself up into a ball (Dawson). In the allied genus *Archiulus*, the segments are not broken up into fragments, as they are in *Xylobius*. The characters of both these genera are so peculiar that they have been placed in a separate family under the name of *Archiulidæ*. Other Myriapods have been discovered in the Carboniferous Rocks of North America and Britain, and have been referred to the genus *Euphoberia*. The true place of

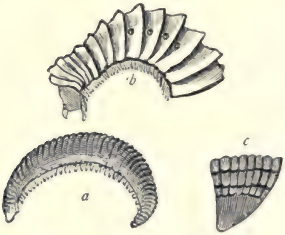


Fig. 127.—*Xylobius Sigillariæ*, a Carboniferous Myriapod. (After Dawson.) *a*, Natural size; *b*, Anterior portion, enlarged; *c*, Posterior portion, enlarged.

these is uncertain, and they seem to have possessed the anomalous character of a row of dorsal spines. In the Lithographic Slates of Solenhofen (Middle Oolites) occur the remains of an animal which is referred to the *Myriapoda* by Count Münster, under the name of *Geophilus proavus*. Other Myriapods have been described from Tertiary strata and from amber.

Class Insecta.

The Insects are *Articulate Animals, in which the head, thorax, and abdomen are distinct from one another. The thorax consists of three segments, each of which carries a pair of legs. Mostly there are two pairs of wings borne by the two hinder segments of the thorax. The abdomen never carries locomotive limbs, but the last abdominal segments may carry reproductive or sensory appendages. A single pair of jointed antennæ is present, and the eyes are generally compound. Respiration is effected by air-tubes* (*tracheæ*).

As regards the general distribution of the *Insecta* in time, the oldest-known forms are from the Devonian Rocks of North America. Here occur the remains of several insects which belong to the order of the Neuropterous Insects (or to the *Pseudo-neuroptera*). Amongst the most remarkable of these is the *Platephemera antiqua* of Mr Scudder (fig. 128). This species must have attained a large size—five inches in expanse of wing—and it is regarded by Mr Scudder as being referable to the *Ephemeridæ* (the May-flies). This eminent authority, however, regards it as a "synthetic type;" that is to say, as a form combining peculiarities of structure which are now only found in different groups.

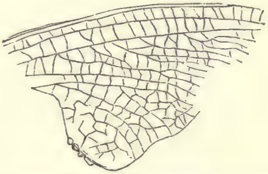


Fig. 128.—Wing of *Platephemera antiqua* (after Dawson), Devonian.

Three other genera belonging to the *Neuroptera* have been described from the Devonian Rocks of North America, under the names *Homothetus*, *Lithentomum*, and *Xenoneura*.

In the Carboniferous Rocks, the remains of Insects, as might have been expected, are comparatively more abundant, though still far from common. In the rocks of this period we have representatives of the orders *Neuroptera*, *Orthoptera*, and *Coleoptera* (Beetles). The *Neuroptera* are represented by a remarkable form, which has been referred to the *Ephemeridæ* under the name of *Haplophlebium Barnesii* (fig. 129). This insect

must have attained a size much larger than that of any recent Ephemerids, measuring fully seven inches in expanse of wing.

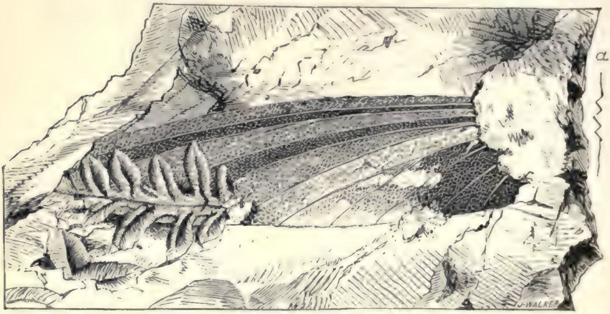


Fig. 129.—*Haplophlebium Barnesii* (after Dawson). From the Carboniferous Rocks of Canada. *a* Profile of base of wing.

Another remarkable Carboniferous insect is the *Archimulacris Acadicus* of Mr Scudder (fig. 130). It belongs to a group of Insects which are tolerably abundant in Carboniferous strata—viz., the Cockroaches; but it does not agree with any living forms.

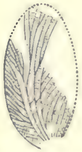


Fig. 130.—*Archimulacris Acadicus* (after Dawson). From the Carboniferous Rocks of Canada.

In the Secondary period, remains of Insects are much more abundant than in any Palæozoic deposit. The Jurassic Rocks have yielded the earliest examples of the orders *Hymenoptera* and *Hemiptera*, whilst the orders *Neuroptera*, *Orthoptera*, and *Coleoptera* are well represented. In the Tertiary Rocks, again, the remains of Insects become still more abundant, and in some deposits they are found in the greatest profusion. Whilst all the above-mentioned orders are represented, the Tertiary Rocks have also yielded the first traces (with doubtful exceptions) of the orders *Diptera* and *Lepidoptera*. Amber, which is, geologically speaking, a very modern product, has yielded the remains of a vast number of insects, all of which belong to extinct forms.

The following are the names of the Orders of Insects which are known in a fossil condition, with the date of their first appearance :—

1. *Neuroptera* (Dragon-flies, White Ants, May-flies, &c.) Devonian.
2. *Orthoptera* (Cockroaches, Crickets, Locusts, &c.) Carboniferous.
3. *Coleoptera* (Beetles). Carboniferous.
4. *Hymenoptera* (Bees, Wasps, Saw-flies, Ants). Jurassic.
5. *Hemiptera* (Aphides, Field-bugs, Cicadas, &c.) Jurassic.
6. *Lepidoptera* (Butterflies and Moths). Tertiary.
7. *Diptera* (House-flies, Flesh-flies, Gnats, Crane-flies, &c.) Tertiary.
8. *Thysanura* (Spring-tails). Late Tertiary (in amber).

CHAPTER XVIII.

SUB-KINGDOM MOLLUSCA.

POLYZOA.

SUB-KINGDOM MOLLUSCA.—The *Mollusca* comprise the animals ordinarily known as Shell-fish, from their commonly possessing an exoskeleton or shell. The Molluscs are *soft-bodied and destitute of any evident segmentation. Commonly the integument secretes a hard calcareous or horny envelope, but this may be absent. The alimentary canal is always present, and never communicates with the body-cavity. The nervous system consists typically of three pairs of ganglia, disposed in a characteristically scattered manner; but in the lower forms a single ganglion alone is present. A heart may or may not be present, and there may or may not be distinct respiratory organs.*

As a matter of course, it is only with the *shell* of the *Mollusca* that the palæontologist has to deal, and those forms which are destitute of this structure are wholly unknown in the fossil condition. The special characters of the shell will be treated of in speaking of the separate classes. In the meanwhile it is sufficient to draw attention to some general considerations. In the Sea-mosses and Sea-mats (*Polyzoa*), the animal is compound, and the hard structures secreted by the colony would not come under the common designation of "shell." In these cases the investment of the colony would rather be termed a "polypidom," and when of a horny nature, it does indeed show a very close resemblance to the "polypary" of the Sertularian Zoophytes. In the Ascidian Molluscs or Sea-squirts (*Tunicata*), the animal is simply enclosed in a leathery or cartilaginous case, in which calcareous matter is very rarely developed. Hence we need feel no surprise that the Tunicaries, with one or two very problematical exceptions,

are not known in the fossil state. The Lamp-shells and their allies (*Brachiopoda*) possess a *bivalve* shell, consisting of two pieces or "valves," which are more or less highly calcareous. Coming to the higher *Mollusca*, the true bivalve Shell-fish (*Lamellibranchiata*), as their common name implies, have also a bivalve shell; but this is distinguished from the shell of the Brachiopods by sufficiently good characters. No Lamellibranch is destitute of a shell, and the remains of this class occur more or less abundantly in all deposits except the most ancient. The ordinary univalve Shell-fish (*Gasteropoda*), as indicated by their common name, have usually a shell composed of a single piece or "valve." In many Gasteropods, however, there is either no shell at all, when the animal is said to be "naked" (as in the Sea-slugs), or the shell is quite rudimentary, and is concealed within the mantle (as in the ordinary slugs). In other Gasteropods again (viz. in the Chitons), the shell is "multivalve," consisting of eight pieces or valves placed one behind the other. Most, however, of the "multivalve" shells of older writers are really referable to the *Cirripedia.* In the minute Oceanic Molluscs which form the class *Pteropoda*, the animal is sometimes naked, but is more usually protected by a symmetrical glassy shell, which is always univalve. In the class of the *Cephalopoda*, finally, great diversity exists in the character of the skeleton. All the ordinary Cuttle-fishes have an *internal* skeleton, embedded in the mantle, and not visible externally. This internal skeleton may be calcareous or horny, and it may be of a very complicated nature; but it merely serves to support the soft parts of the animal, and it does not form an external case in which the animal lives. In one Cuttle-fish only (viz., the Argonaut or Paper Nautilus), is there an external shell, but the nature of this is quite peculiar, and it cannot be compared with the shell of any of the ordinary Molluscs. In another group of the *Cephalopoda*, represented at the present day by the Pearly Nautilus, there is a well-developed external shell, which is always composed of a single piece, and is always chambered, the animal living in the last and largest chamber of the shell.

In composition the shell of the higher *Mollusca* consists of carbonate of lime—usually having the atomic arrangement of calcite—with a small proportion of animal matter. In the *Pholadidæ*, however, the calcareous matter exists in the allotropic condition of arragonite, which is very much harder than calcite. As regards their texture, three principal varieties of shells may be distinguished—viz., the "porcellanous," the "nacreous," and the "fibrous." In the nacreous or pearly

shells, as seen in "mother-of-pearl," the shell has a peculiar lustre, due to the minute undulations of the edges of alternate layers of carbonate of lime and membrane. The "fibrous" shells are composed of successive layers of prismatic cells. The "porcellanous" shell has a more complicated structure, and is composed of three layers or strata, each of which is made up of very numerous plates, "like cards placed on edge." The direction in which these vertical plates are placed, is sometimes transverse in the central layer, and lengthwise in the two others; or longitudinal in the middle, and transverse in the outer and inner strata.

From their so commonly possessing hard structures, whether external or internal, no fossils are more abundant or important than Molluscs. As regards the general distribution of the *Mollusca* in time, the sub-kingdom commences its existence in the Cambrian period, and there is no reason to suppose that this is really its first appearance. In the Cambrian Rocks, the classes of the *Polyzoa*, *Brachiopoda*, *Pteropoda*, *Gasteropoda*, and *Cephalopoda* are certainly represented, and the *Lamellibranchiata* existed in Lower Silurian times, if not earlier. Speaking generally, the chief representatives of the *Mollusca* in Palæozoic time are the chambered Cephalopods (*Tetrabranchiata*) and the *Brachiopoda;* in Mesozoic time, the Cuttlefishes (Dibranchiate Cephalopods), the chambered Cephalopods, and the *Polyzoa;* in Kainozoic time, the Lamellibranchs and Gasteropods. The *Polyzoa* are comparatively poorly represented in Palæozoic Rocks, and attain their maximum towards the close of the Mesozoic period. The *Brachiopods* are vastly more abundant in Palæozoic deposits than in Mesozoic, and have gradually declined to the present day. The *Lamellibranchiata* seem to have been gradually increasing in importance since their first appearance in the Lower Silurian seas, and they have attained their maximum at the present day. The *Gasteropods*, upon the whole, like the Bivalves, seem to have reached their culminating point in recent seas; whilst the *Pteropods* seem to have been as abundant in Silurian seas as they are at present. The history of the *Cephalopoda* is a remarkable one. The *Tetrabranchiate* forms, with chambered shells, attained their maximum in the earlier portion of the Silurian period, as regards their simpler types; but the more complex types of the group swarmed in the seas of the Secondary period, and finally disappeared at the close of this epoch. This group at the present day is represented solely by the Pearly Nautilus. The *Dibranchiate Cephalopoda*, on the other hand, represented at the present day by the Cuttle-

fishes, did not make their appearance till the commencement of the Secondary period, and seem to have reached their maximum in existing seas.

The sub-kingdom *Mollusca* is divided into two great divisions, termed respectively the *Molluscoida* and the *Mollusca Proper*. The division *Molluscoida* comprises the three classes of the *Polyzoa*, *Tunicata*, and *Brachiopoda*, characterised by having *a nervous system consisting of a single ganglion or principal pair of ganglia, whilst there is either no distinct organ of the circulation or an imperfect heart.* In the division of the *Mollusca Proper* are comprised the classes of the *Lamellibranchiata* (Bivalves), *Gasteropoda* (Univalves), *Pteropoda*, and *Cephalopoda*. All these classes are distinguished by having *a nervous system composed of three principal pairs of ganglia; whilst there is a well-developed heart, consisting of at least two chambers.*

Class Polyzoa or Bryozoa.

Animal composite, forming colonies, all the members of which are produced by budding from a primitive being (zoöid). Each member of the colony (zoöid) is enclosed in a double-walled sac, the outer coat of which is mostly hardened by horny or calcareous matter. There is no heart, and the mouth is surrounded by a circle or crescent of hollow ciliated tentacles. The colonies are all but invariably fixed to some foreign object, and are in many cases plant-like in form.

All the *Polyzoa* live in an associated form in colonies or "polyzoaria," which are sometimes foliaceous, sometimes branched and plant-like, sometimes encrusting, and very rarely are free. Each "polyzoarium" consists of an assemblage of distinct but similiar zoöids arising by continuous gemmation from a single primordial individual. The colonies thus produced are in very many respects closely similar to those of many of the Hydroid Polypes, with which, indeed, the *Polyzoa* were for a long time classed. The "polyzoarium," however, of a *Polyzoön* differs from the polypidom of a composite Hydroid in the *general* fact that the separate cells of the former do not communicate with one another otherwise than by the continuity of the external integument; whereas the zoöids of the latter are united by an organic connecting medium, or "cœnosarc," from which they take their origin. On this point Mr Busk observes:—

"It has been before said that the *Polyzoa* are always associated into compound growths, made up of a congeries of individuals, which, though distinct, yet retain some degree of

intercommunication, comparable in kind perhaps, though not in degree, to what obtains in many of the compound Ascidians. That this community exists is proved by the otherwise inexplicable circumstance that the polyzoaria in many instances present elements common to the whole growth, and not belonging specially to any individual. The chief bond of connection would appear to reside partly in the continuity of the external integument, and partly also, in all probability, in a slow interchange of the vital fluid with which the cavities of the cells are charged."

In one sub-order of the *Polyzoa* (*Ctenostomata*), the polyzoarium consists of a series of cells arising from a common tube, but this exception does not affect the value of the above *general* distinction between the *Polyzoa* and the *Hydroida*.

A second point of difference is found in the invariably corneous (or chitinous) texture of the polypidoms of the *Hydroida*, whereas those of the *Polyzoa* may be corneous or fleshy, but are in the majority of instances more or less highly charged with carbonate of lime.

As before remarked, the colonies of the *Polyzoa* are produced by a process of continuous budding from a primitive being or zoöid. The budding takes place according to a determinate law, differing in different forms, and the resulting colony varies in shape according to the method of budding in each species. All the zoöids of the colony are termed "polypides," and the entire colony consists simply of an aggregation of precisely similar polypides, which may be simply united by their external integuments or, more rarely, spring from a common tube. It is only with the outer investment of the colony that the palæontologist has to deal; but it may be well briefly to describe the structure of a typical polypide.

The polypide of a *Polyzoön* (fig. 131, 2) consists essentially of a double-walled sac, filled with fluid, and perforated by an aperture where the mouth of the polypide is situated. In the majority of cases the outer wall of the sac (termed the "ectocyst") is of a horny consistence, or may be more or less highly calcareous. It forms a little chamber, which is technically called the "cell." At one point, varying in its position, the cell is furnished with an aperture or "mouth" (fig. 131, 1), whence the polypide can protrude its tentaculate head. The inner wall of the sac (termed the "endocyst") is invariably flexible and membranous, and the space included within it is filled with fluid, in which floats the alimentary canal. The commencement of the alimentary canal is surrounded by a series of hollow ciliated tentacles, which are mostly arranged

in a circle in the marine *Polyzoa*, but are disposed in the shape of a horse-shoe in most of the fresh-water forms. The digestive canal passes through the body-cavity, without opening into it, and terminates in a distinct anus placed near the mouth. The only other organs possessed by the polypide are a nervous ganglion, and the organs of reproduction, each zoöid being hermaphrodite.

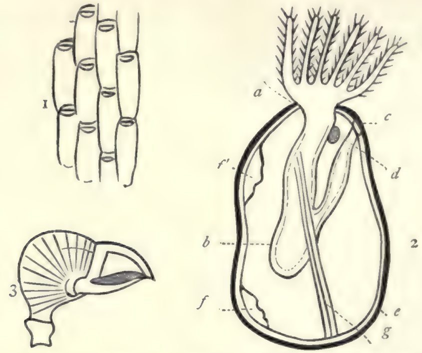


Fig. 131.—Morphology of Polyzoa. 1. Portion of the cœnœcium of *Flustra truncata*, magnified. 2. Diagram of a Polyzoön (after Allman): *a* Region of the mouth surrounded by tentacles; *b* Alimentary canal; *c* Anus; *d* Nervous ganglion; *e* Investing sac (ectocyst); *f* Testis; *f'* Ovary; *g* Retractor muscle. 3. Bird's-head process, or "avicularium," of a Polyzoön.

In order, then, to arrive at a clear conception of the structure of a *Polyzöon*, we have simply to imagine that such a polypide as above described should have the power of repeating itself by gemmation, "thus producing one or more precisely similar systems, holding a definite position relatively to one another, while all continue organically united."

The only element of the *Polyzoa* with which the palæontologist is concerned is the external investment of the colony—the "cœnœcium" or "polyzoarium." This is formed by the combined ectocysts of the various polypides, and it varies greatly both in form and actual composition. In form, it may be plant-like, rooted at one point, and rising into foliaceous expansions or arborescent growths; or it may spread over some foreign object as a continuous crust. In consistence, it may be fleshy, horny, sub-calcareous, or completely calcareous;

the simply fleshy forms, as a matter of course, never occurring in a fossil condition.

The form of the "cell," formed by the ectocyst or outer wall of each polypide, varies considerably, and important distinctions may be drawn from this character alone. In one large group of the *Polyzoa*—the *Cheilostomata*—the mouth of the cell is never quite terminal in position, but is always placed upon the front of the cell, generally close to one end (fig. 132); whilst the diameter of the mouth is less than the diameter of the cell. In most of these forms, also, the mouth of the cell is provided with a movable lid or shutter, by which it can be closed when the animal is retracted within it. In another great group —the *Cyclostomata*—the cells are tubular in form, and the mouth is terminal in position, whilst its diameter usually equals that of the cell. In these forms, also, there is no special apparatus for the closure of the mouth of the cell.

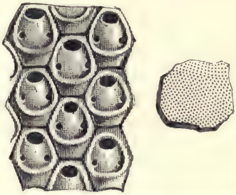


Fig. 132.—*Escharina Oceani*, showing the sub-terminal mouths of the cells. Upper Cretaceous.

The surface of the cell may be "either smooth and entire, spinous or granulous; perforated with minute pores, or cribriform with larger openings; reticulate or ribbed, &c.,—all of which conditions, with certain precautions, afford excellent diagnostic characters" (Busk). The margins of the mouth of the cell, also, may be "simple or thickened, unarmed or beset with erect 'marginal spines,' which again may be either rigid or articulated at the base, simple or branched."

There still remain three structures which are present in many forms, and especially in the *Cheilostomata*, which require some notice. The structures in question are known as the "ovicell," the "avicularia," and the "vibracula."

The "ovicell" is a structure especially characteristic of the Cheilostomatous *Polyzoa;* but its presence is not universal, and when present it may be inconspicuous. Its general form is that of "a more or less rounded eminence situated above or behind the cell. . . . The cavity of the organ is continuous with the perivisceral space, through a passage situated at the upper and back part of the cell, and through which it would appear the ova are conveyed as into a sort of marsupial pouch. This organ is wanting in the *Cyclostomata*, in which its functions are

apparently supplied by a dilatation of the body of the cell itself." (Busk.)

The "avicularia" and "vibracula" are peculiar appendages of the ectocyst, supposed to be weapons of offence and defence, or to subserve some unknown function in the economy of the colony, and believed by Huxley to be peculiarly modified polypides. The avicularia, or "bird's-head processes," differ a good deal in shape, but consist essentially of a "movable mandible and a cup furnished with a horny beak, with which the point of the mandible is capable of being brought into apposition" (Busk).—In shape they are often closely similar to the head of a bird (fig. 131, 3), and they perform a peculiar snapping movement, which is continued long after the apparent death of the colony. In many respects, the avicularia are comparable with the "pedicellariæ" of the Sea-urchins and Star-fishes. In the "vibracula," the place of the mandible of the avicularium is taken by a bristle or seta, which is capable of extensive movement.

The following table exhibits the leading groups of the *Polyzoa* :—

Table of the Divisions of the Polyzoa.

Order I.—Phylactolæmata.

Tentacles arranged in the shape of a horse-shoe or crescent. Mouth furnished with a valve-like organ or "epistome."

Sub-order 1. *Lophopea* (fresh-water).—Arms of the tentacular disc ("lophophore") free or obsolete ; consistence, horny or sub-calcareous.

Sub-order 2. *Pedicellinea* (marine).—Arms of the tentacular disc united at their extremities ; consistence, soft and fleshy.

Sub-order 3. *Rhabdopleurea* (marine).—Cœnœcium branched, adherent, membranous, with a chitinous rod on its adherent side. Tentacular disc horse-shoe-shaped. No epistome (?)

Order II.—Gymnolæmata.

Tentacles arranged in the form of a more or less complete circle. No valve-like organ, or "epistome," arching over the mouth.

Sub-order 4. *Paludicellea* (fresh-water).—Polypide completely retractile ; evagination of tentacular sheath imperfect ; consistence, horny or sub-calcareous.

Sub-order 5. *Cheilostomata* (marine).—Polypide completely retractile ; evagination perfect ; orifice of cell sub-terminal, of less diameter than the cell, and usually closed with a movable lip or shutter, sometimes by a contractile sphincter ; cells not tubular ; consistence, calcareous, horny, or fleshy.

Sub-order 6. *Cyclostomata* (marine).—Cell tubular ; orifice terminal, of the same diameter as the cell, without any movable apparatus for its closure; consistence, calcareous.

Sub-order 7. *Ctenostomata* (marine).—Orifice of the cell terminal, furnished with a usually setose fringe for its closure ; cells distinct, arising from a common tube ; consistence, horny or carnose.

Of the above sub-orders of the *Polyzoa*, only the marine groups of the *Cheilostomata* and *Cyclostomata* are known to occur in the fossil condition; their preservation being due to their marine habits and their general possession of a calcareous or sub-calcareous cœnœcium. The general facts as to the distribution of the *Polyzoa* in past time have been already alluded to. The *Oldhamia* of the Cambrian Rocks and the Graptolites have been referred to the *Polyzoa;* but the former is probably a plant, and the latter almost certainly belong to the *Hydrozoa.* Leaving these out of account, the *Polyzoa* seem to commence in the Upper Cambrian, and are well represented in the Silurian, Devonian, Carboniferous, and Permian Rocks, but especially in the Carboniferous. None of the Palæozoic genera extend into the Secondary period. In the Secondary period *Polyzoa* are very abundant, and they attain their maximum of development in the Cretaceous period, the Chalk having yielded over two hundred species belonging to this class. In the Tertiary period, also, *Polyzoa* are abundant; the Coralline Crag (Pliocene) deriving its name from the great profusion of its Polyzoan remains.

Of the Palæozoic *Polyzoa* the most important forms belong to the family of the *Fenestellidæ* or "Lace-corals." These commence in the Lower Silurian, and extend to the Permian; but they are especially characteristic of the Carboniferous Rocks. In *Fenestella* itself (fig. 133), the cœnœcium forms a

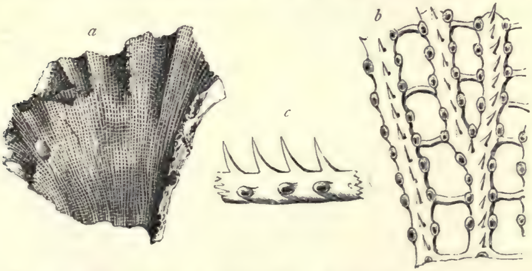


Fig. 133.—*Fenestella Lyelli.* *a* Natural size; *b* Portion enlarged; *c* Cells and spines in profile. From the Carboniferous Rocks of Canada (after Dawson).

funnel-shaped or fan-shaped expansion, the base of which is attached to some foreign object. The cœnœcium is composed of a number of nearly parallel stems, united to one another by numerous cross-bars or dissepiments, enclosing small inter-

spaces. The outer surface of the branches is minutely porous or longitudinally striated. The inner surface of the branches exhibits a central ridge or keel, separating the mouths of two rows of cells. Sometimes there is an additional row of cells on the mesial keel, and the dissepiments are usually destitute of cells. The entire cœnœcium is calcareous. In the nearly allied genus *Retepora*, the cœnœcium is also a fan-shaped expansion, and is also of a calcareous consistence. In place, however, of transverse dissepiments, the branches of the cœnœcium unite with one another in such a manner as to form ovate interspaces or "fenestrules." The outer surface of the cœnœcium is non-celluliferous and minutely striated. The inner surface bears several rows of small cells.

In the genus *Ptilopora* (fig. 134) are forms essentially similar

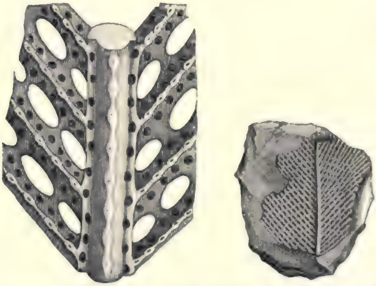


Fig. 134.—*Ptilopora pluma*; the right-hand figure of the natural size, the left-hand figure enlarged. Carboniferous.

to *Fenestella*, but having a feather-like arrangement, consisting of a central stem giving off lateral branches, which are connected by dissepiments, leaving oval fenestrules. In *Glauconome* (*Acanthocladia*, King) are forms in which the cœnœcium consists of a central axis giving off lateral branches, which bear longitudinally-disposed cellules, but which are not united by transverse dissepiments. Lastly, in *Archimedipora*, which is found abundantly in parts of the Carboniferous series of the United States, the cœnœcium is wound in an oblique spiral round a central axis. The only other Palæozoic genus of any special importance is *Ptilodictya*, the species of which are especially characteristic of the Silurian Rocks. In this genus, the cœnœcium is flattened, foliaceous, or more commonly

dichotomously branched. The cellules are placed obliquely on both sides of the cœnœcium, and have prominent oval mouths.

In the Secondary period, the remains of *Polyzoa* are abundant, and some of the genera are still represented in recent

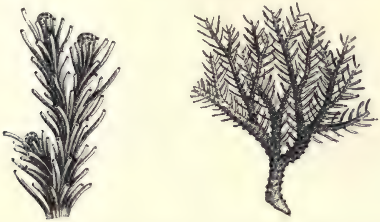


Fig. 135.—*Entalophora cellarioides*, natural size and enlarged. Oolites.

seas. Nearly twenty genera are known from the Jurassic Rocks, amongst which may be mentioned *Idmonea*, *Eschara*, *Defrancia*, *Diastopora*, *Bidiastopora*, (fig. 136), and *Entalophora*

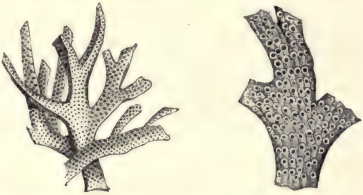


Fig. 136.—*Bidiastopora cervicornis*, natural size and enlarged. Oolites.

(fig. 135). All of these, except *Eschara*, belong to the group of the *Cyclostomata*, distinguished by their tubular cells, the mouth of which equals in breadth the diameter of the cell.

It is in the Cretaceous period that the *Polyzoa* attain their maximum, nearly two hundred species being known in the Chalk. Most of the Cretaceous forms belong to the *Escharidæ*, the genus *Eschara* being abundantly represented. All the members of this family belong to the group of the *Cheilostomatous Polyzoa*, in which the orifice of the cell is not terminal, and is of less diameter than the cell itself.

In the Tertiary Rocks *Polyzoa* are likewise abundant, and many of the genera are represented at the present day by

living forms. One of the greatest depots of fossil *Polyzoa* is the White Crag of Suffolk, which is for this reason very inappropriately called the "Coralline Crag." Amongst the more important Tertiary genera may be mentioned *Eschara*, *Cellepora*, *Flustra*, *Tubulipora*, *Idmonea*, and *Fascicularia* (or *Meandropora*). One of the most singular of these is the genus *Fascicularia* (fig. 137), in which the cœnœcium is more or less

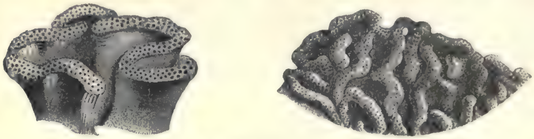


Fig. 137.—*Fascicularia* (*Meandropora*) *cerebriformis*, Miocene Tertiary.

spherical, composed of vertical laminæ arranged somewhat like the convolutions of the brain, and carrying the cell-mouths at their extremities.

CHAPTER XIX.

BRACHIOPODA.

THE *Brachiopoda* are defined as *Molluscous animals in which the body is protected by a bivalve shell, which is lined by expansions of the integument or "mantle." The mouth is furnished with long, spirally-coiled; cirriferous processes or "arms." The animal is never composite.* (Fig. 138).

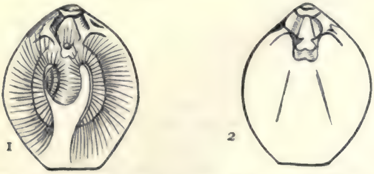


Fig. 138.—Brachiopoda.—*Terebratula vitrea*. 1. Showing the ciliated "arms;" 2. Showing the shell with its loop. (After Woodward.)

The *Brachiopoda* are essentially very similar in structure to the *Polyzoa*, from which they are distinguished by the fact that

they are never composite, and by the possession of a bivalve, calcareous, or sub-calcareous shell. They are commonly known as "Lamp-shells," and are all inhabitants of the sea. All the living forms are fixed to some solid object in their adult condition; but there is good reason to believe that many of the fossil forms were unattached and free in their fully-grown condition. From the presence of a bivalve shell, the Brachiopods have often been placed near the true bivalve Molluscs (the *Lamellibranchiata*); but their organisation is very much inferior, and there are also sufficient differences in the shell to justify their separation.

The two valves of the shell in any Brachiopod are articulated together by an apparatus of teeth and sockets, or are kept in apposition by muscular action alone. As regards the contained animal, the position of the valves is anterior and posterior, so that they are properly termed the "ventral" and "dorsal" valves. One of the valves is always slightly, sometimes greatly, larger than the other, so that the shell is said to be "inequivalve" (fig. 139). On the other hand, a line drawn vertically

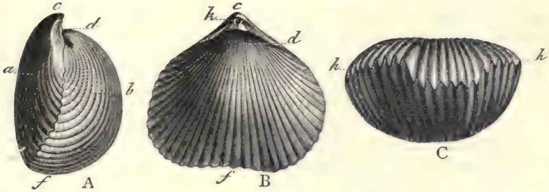


Fig. 139.—*Rhynchonella sulcata.* A, Profile view. B, View of the dorsal surface. C, View of the base. *a* Ventral valve; *b* Dorsal valve; *f* Base; *c* Beak; *h* Foramen. Lower Cretaceous.

from the beak of the shell to its base (in fig. 139 B, from *c* to *f*), would divide it into two equal halves, so that the shell is said to be "equilateral." In the true bivalve Shell-fish (*Lamellibranchiata*), on the contrary, the valves of the shell are placed upon the sides of the contained animal, so that they are "right" and "left," instead of being dorsal and ventral. Further, the two valves are usually of the same size ("equivalve"), and a line drawn from the beak to the base would almost always divide the shell into unequal halves; so that the shell is "inequilateral."

Ordinarily the ventral valve of the shell of the Brachiopods is the largest of the two, and it is generally furnished with a prominent curved "beak." Very commonly the beak is per-

forated by a larger or smaller aperture, which is termed the "foramen" (fig. 139, B), and which serves for the transmission of a muscular peduncle or stem by which the shell is attached to some foreign object. In some cases, however (as in *Lingula*), the peduncle simply passes between the apices of the valves, and there is no foramen; whilst in others (as in *Crania*, fig. 161), the shell is merely attached by the substance of the ventral valve. The dorsal valve, which is also usually the smallest, is always free, and is never perforated by a foramen. Further, as already remarked, there is reason to believe that many fossil forms were free and unattached in their adult condition.

In most living Brachiopods the valves are articulated to one another by two teeth which are developed upon the ventral valve, and fit into corresponding sockets in the dorsal valve. Behind the dental sockets of the dorsal valve there is usually a prominent process ("cardinal process"), to which are attached two "cardinal muscles." These are inserted on each side of the centre of the ventral valve, and serve to open the shell. The valves of the shell are closed by proper "adductor muscles" (usually four in number), which also pass between the valves; and in those in which hinge-teeth are wanting, it is by these muscles that the valves are kept together. These muscles leave "scars" or impressions at their points of insertion and origin: and the number and form of these scars afford important diagnostic characters to the palæontologist.

Very commonly, the beaks of the dorsal and ventral valves are separated from one another by a narrower or wider space, which is termed the "hinge-area" (fig. 140). In some genera,

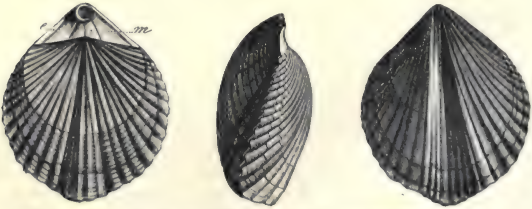


Fig. 140.—*Terebratella Astieriana*, Cretaceous. *e* Hinge-area; *m* Deltidium.

as in *Spirifera*, the area is very conspicuous; in other cases it is very narrow, or even does not exist. In front of the foramen of the ventral valve, and very often forming part of its circumference, there is commonly a triangular plate, which may be

composed of one or two pieces, and which is termed the "deltidium" (fig. 140, *m*). In other cases this structure is altogether wanting.

In intimate structure, the shell of most of the *Brachiopoda* (fig. 141) consists "of flattened prisms, of considerable length, arranged parallel to one another with great regularity, and at a very acute angle—usually only about 10° or 12°—with the surfaces of the shell."—(Carpenter.) In most cases, also, the shell is perforated by a series of minute canals, which pass from one surface of the shell to the other, in a more or less vertical direction, usually widening as they approach the external surface. These canals give the shell a "punctated" structure, and in the living animal they contain cæcal tubuli, or prolongations, from the mantle, which are considered by Huxley as analogous to the vascular processes by which in many Ascidians the muscular tunic, or "mantle," is attached to the outer tunic, or "test." In some of the *Brachiopoda* (as in the *Rhynchonellidæ*) the shell is "impunctate," or is devoid of this singular canal system.

Fig. 141.—Minute structure of the shell of *Terebratula*, showing the flattened prisms of the shell, and the canals.

The inner surface of the valves of the shell is lined by expansions of the integument which secrete the shell, and are called the "lobes" of the "pallium," or "mantle." The digestive organs and muscles occupy a small space near the beak of the shell, which is partitioned off by a membranous septum, which is perforated by the aperture of the mouth. The remainder of the cavity of the shell is almost filled by two long oral processes, which are termed the "arms," and from which the name of the class has been derived (fig. 138, 1). These organs are lateral prolongations of the margins of the mouth, usually of great length, closely coiled up, and fringed on one side with lateral processes, or "cirri." In many Brachiopods the arms are supported upon a more or less complicated internal calcareous framework or skeleton, which is sometimes called the "carriage-spring apparatus."

In some forms, as in the typical *Terebratulæ* (fig. 138, 2), the internal skeleton which supports the arms is a short shelly loop, of a very simple character. In these cases it is only at their bases that the arms are supported, and they are therefore more or less movable. In other cases, as in the *Spiriferidæ* (fig. 142), the arms must have been immovable, as they are supported by two thin spirally-rolled lamellæ, which form two

calcareous spires in the interior of the dorsal valve. In some cases, the whorls of these spires are in turn furnished with minute calcareous spines, showing that the cirri of the arms

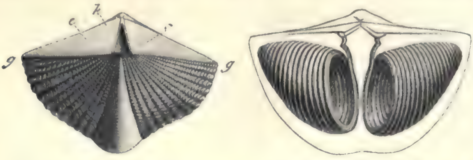


Fig. 142.—*Spirifera hysterica*, Carboniferous. The right-hand figure shows the interior of the dorsal valve, with the calcareous spires for the support of the arms.

were also supported by an internal skeleton. The form and development of the calcareous supports of the arms, though liable to vary with age, nevertheless furnish important characters in the discrimination of fossil Brachiopods.

The *Brachiopoda* may be divided into two groups, called respectively the *Articulata* and *Inarticulata*. In the former the valves of the shell are united along a hinge-line, the lobes of the mantle are not completely free, and the intestine ends cæcally. In this group are the recent *Terebratulidæ* and *Rhynchonellidæ*. In the *Inarticulata* the valves of the shell are not united along a hinge-line, the mantle-lobes are completely free, and the intestine terminates in a distinct anus. In this group are the *Craniadæ*, *Discinidæ*, and *Lingulidæ*.

The Brachiopods are of such importance as fossils that the characters of the more important groups, with their geological range, and leading genera will here be given, along with figures of the commoner types. As regards the general distribution of the class in time, the *Brachiopoda* are found from the Cambrian Rocks up to the present day, and present us with an example of a group which appears to be slowly dying out. Nearly two thousand extinct species have been described, and the class appears to have attained its maximum in the Silurian epoch, which is, for this reason, sometimes called the "Age of Brachiopods." Numerous genera and species are found also in both the Devonian and Carboniferous formations. In the Secondary Rocks *Brachiopoda* are still abundant, though less so than in the Palæozoic period. In the Tertiary epoch a still further diminution takes place, and at the present day we are not acquainted with a hundred living forms. Of the families of *Brachiopoda*, the *Productidæ*, *Strophomenidæ*, and *Spiriferidæ* are the more important extinct types. Of the genera, the most

persistent is the genus *Lingula*, which commences in the Cambrian Rocks, and has maintained its place up to the present day, though it appears to be gradually dying out.

According to Woodward :—"The hingeless genera attained their maximum in the Palæozoic age, and only three now survive (*Lingula*, *Discina*, *Crania*)—the representatives of as many distinct families. Of the genera with articulated valves those provided with spiral arms appeared first, and attained their maximum while the *Terebratulidæ* were still few in number. The subdivision with calcareous spires disappeared with the Liassic period, whereas the genus *Rhynchonella* still exists. Lastly, the typical group, *Terebratulidæ*, attained its maximum in the Chalk period, and is scarcely yet on the decline."

Of the families of the *Brachiopoda*, the *Productidæ* and *Strophomenidæ* are exclusively Palæozoic. The *Spiriferidæ* are mainly Palæozoic, but extend into the Lias, where they finally disappear. The *Lingulidæ* commence in the Cambrian period, and have survived to the present day. The *Rhynchonellidæ*, *Craniadæ*, and *Discinidæ* commence in the Silurian period, and are represented by living forms in existing seas. The *Koninckinidæ* are exclusively Triassic. The *Thecididæ* extend from the Trias to the present day; and the *Terebratulidæ* appear to commence in the Devonian, and are well represented by living forms. In the following are given the leading characters and more important forms of the families of the *Brachiopoda*:*—

FAM. I. TEREBRATULIDÆ.—Shell minutely punctate: ventral valve with a prominent beak, perforated by a foramen for the emission of a muscular peduncle, whereby the animal is fixed to some submarine object. Foramen partially surrounded by a deltidium of one or two pieces. Arms entirely or partially supported by calcified processes, usually in the form of a loop, and always fixed to the dorsal valve (fig. 143.)

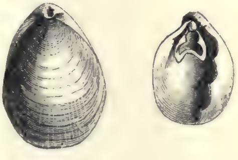


Fig. 143.—*Terebratula sacculus*, Carboniferous. The right-hand figure shows the interior of the dorsal valve with the loop. (After Dawson.)

In the genus *Terebratula* itself, and in *Terebratulina*, the loop supporting the arms is very short, the former commencing

* Most of the details of this section are taken from the magnificent Monograph of the Brachiopoda, published by the Palæontographical Society, and written by Thomas Davidson, Esq., F.R.S., the greatest living authority upon the subject of the Brachiopods.

in the Devonian period, the latter in the Oolitic, and both being represented by living forms. In the genus *Waldheimia* there is a very long loop, which is bent backwards, and the same is the case with *Terebratella.* The former appears to commence in the Trias, the latter in the Cretaceous Rocks, and both have survived to the present day. Forming a section of the *Terebratulidæ*, or sometimes regarded as a separate family, are the two or three species which make up the genus *Stringocephalus.* These (fig. 144) are all Devonian, and are characterised by the possession of a long loop, and a widely-punctated shell. The beak of the ventral valve is very prominent, and is pierced by a foramen, which is large in the young, and small in the adult shell; and the ventral valve has a well-developed mesial septum.

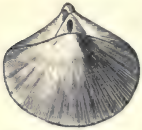


Fig. 144.—*Stringocephalus Burtini*, Devonian.

Fam. II. Thecididæ.—Shell fixed to the sea-bottom by the substance of the beak of the larger or ventral valve; structure punctated. Oral processes (arms) united in the form

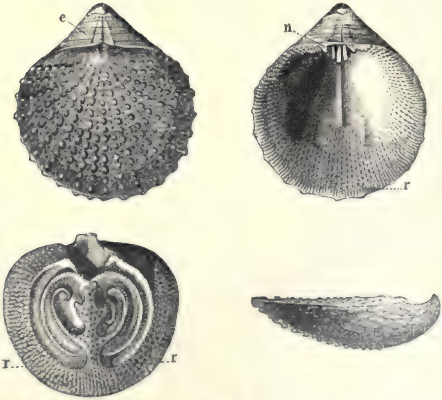


Fig. 145.—*Thecidium papillatum.* *e* Hinge-area; *n* Hinge-teeth of ventral valve; *r r* Granulated border of the interior of the dorsal valve.

of a bridge over the visceral cavity; cirrated arms folded upon themselves, and supported by a calcareous loop. (Fig. 145.)

The members of this family are all attached to some foreign body by a portion of the beak of the ventral valve, which, in the adult state, has either no foramen, or an exceedingly small one. The ventral valve has a well-marked hinge-area and an indistinct triangular deltidium. All the known species belong to the single genus *Thecidium*, represented at the present day by a single living species. In time, the genus *Thecidium* seems to have commenced in the Upper Trias, and is well represented in parts of the Jurassic and Cretaceous Series.

FAM. III. SPIRIFERIDÆ.—Animal free when adult, or rarely attached by a muscular peduncle. Shell punctated or unpunctated. Arms greatly developed, and entirely supported upon a thin, shelly, spirally-rolled lamella (fig. 142 and fig. 146.)

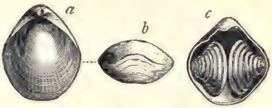
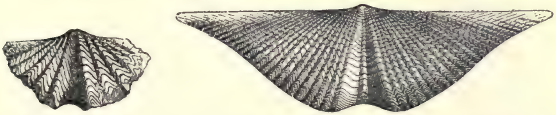


Fig. 146.—*Athyris subtilita.* Lower Carboniferous. The right-hand figure shows the interior of the dorsal valve, with the spiral supports for the arms. (After Dawson.)

The family of the *Spiriferidæ* is pre-eminently Palæozoic, but several forms extend into the older Secondary Rocks. No member of the family, however, has yet been found in rocks younger than the Lias. Of the genera of the family, in the genus *Spirifera*, or *Spirifer* (fig. 148), the valves of the shell are articulated by teeth and sockets, and the shell is not punctated. The hinge-area is divided across in each valve by a triangular fissure, which in the ventral valve is closed more or less com-


Figs. 147 and 148.—*Spirifera sculptilis*, Devonian. *Spirifera mucronata*, Devonian.

pletely by a pseudo-deltidium, and in the dorsal valve is occupied by the cardinal process. The true Spirifers are mainly Silurian and Devonian, and the forms of the latter formation often have the shell winged, or drawn out at the lateral angles (fig. 148). The genus *Spiriferina* differs from Spirifer chiefly in having the shell punctated, and extends from the Devonian to the Lias. In the genus *Cyrtia*, the shell is impunctate, and the deltidium is perforated by a small

foramen. This genus extends from the Upper Silurian to the Trias. In the genus *Athyris* (fig. 146) there is no hinge-area or deltidium, and the beak of the ventral valve does not appear to be perforated by a foramen in the adult condition. All the species of *Athyris* appear to be Palæozoic, and they are especially characteristic of the Devonian period. In the genus *Spirigera* (including *Retzia*) there is no true hinge-area, and the beak of the ventral valve is terminated by a round foramen, with a distinct deltidium. The members of this genus extend from the Silurian to the Trias. In the genus *Uncites* the shell

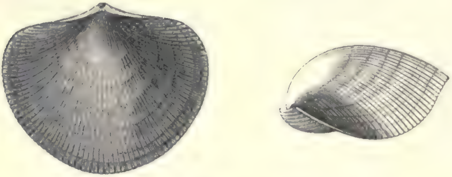


Fig. 149.—*Atrypa* (*Spirigerina*) *reticularis*, Silurian.

is impunctate, there is no hinge-area, and the ventral valve has a long incurved beak, which is perforated in the young shell by a small foramen. The genus is, so far as known, exclusively Devonian. Lastly, in the genus *Atrypa* (fig. 149) the shell is impunctate, and the beak of the ventral valve is long and incurved. The beak is perforated by a small foramen, completed by a deltidium. Owing to the curvature of the beak, however, this foramen is often concealed, so that the beak seems to be imperforate; hence the name of the genus (Gr. *a*, without; *trupa*, aperture.) It is probable that the shell was unattached in the later portions of its existence. The genus is exclusively Palæozoic, appearing to be confined to the Silurian and Devonian formations. The best-known species is *A. reticularis*, figured above.

Fig. 150. — *Koninckia Leonhardi*, showing the spiral supports for the arms. Trias.

FAM. IV. KONINCKINIDÆ.—Animal unknown. Shell free; valves unarticulated (?). Oral arms supported by two lamellæ spirally coiled (fig. 150).

The only genus of this family is *Koninckia*, represented by

the single species *K. Leonhardi* of the Trias of St Cassian. The shell resembles *Producta* in being eared, and the dorsal valve is concave, and follows the curve of the ventral valve. It differs from *Producta* in having the arms supported upon spiral processes.

FAM. V. RHYNCHONELLIDÆ.—Animal free, or attached by a muscular peduncle issuing from an aperture situated under the extremity of the beak of the ventral valve. Arms spirally rolled, flexible, and supported only at their origin by a pair of short, curved, shelly processes. Shell-structure fibrous and impunctate. (Fig. 151.)

Fig. 151.—*Rhynchonella capax*; dorsal, profile, and ventral views. Lower Silurian.

The *Rhynchonellidæ* range from the Lower Silurian to the present day, in the person of the genus *Rhynchonella* itself; but the remaining genera of the family are exclusively Palæozoic. The genus *Rhynchonella* (fig. 151) has the valves more or less convex, smooth or plaited, united by teeth and sockets. The shell is trigonal, generally with a mesial fold and sinus (fig. 139), and having the beak of the ventral valve acute, incurved, or prominent. The foramen is situated under the beak, open to view, or concealed, and entirely or partially completed by a deltidium. The species of the genus *Rhynchonella* are very abundant in both Palæozoic and Mesozoic deposits, and two species are known at the present day.

In the genus *Pentamerus* (fig. 152), the shell is ovate, the valves articulated by teeth and sockets, generally ribbed or striated, but sometimes smooth.

The beaks are incurved, that of the ventral valve concealing a triangular fissure. Inside the ventral valve "two contiguous vertical septa coalesce into one median plate, extending from the beak to a greater or less distance; and then diverge and form the dental plates, enclosing a triangular chamber of much smaller dimensions than the lateral ones."—(Davidson.) The small central chamber must have been occupied by the digestive organs, and the spiral arms must have filled the great

lateral spaces. In the interior of the smaller or dorsal valve are two longitudinal septa, which often form a chamber corresponding to and apposed to the median chamber in the ven-

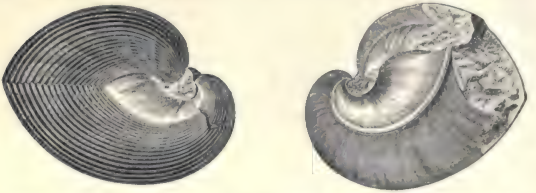


Fig. 152.—*Pentamerus Knightii.* The right-hand figure shows the internal septa and dental plates of the shell. Upper Silurian.

tral valve. The *Pentameri* range from the Lower Silurian to the Carboniferous inclusive; but they are especially characteristic of that portion of the Silurian series known as the Llandovery formation. They often occur in the greatest profusion, and the species have in many cases an enormous geographical range.

The two other genera generally placed in the *Rhynchonellidæ*—viz., *Camarophoria* and *Porambonites*, are of little importance. The former is confined to the Carboniferous and Permian deposits, and the latter occurs exclusively in strata of Lower Silurian age.

Fam. VI. Strophomenidæ.—Animal unknown; some probably free—others attached, during the whole or a portion of their existence, by a muscular peduncle. No calcified supports for the arms. Shell with a straight hinge-line and a low triangular area in each valve. Shell-structure fibrous or punctated. The *Strophomenidæ* are exclusively Palæozoic, and include the

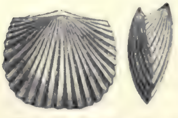


Fig. 153.—*Orthis Davidsoni;* dorsal and side view. Silurian.

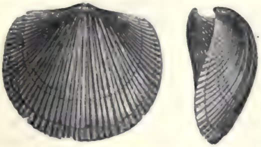


Fig. 154.—*Orthis porcata;* dorsal and side view. Silurian.

genera *Orthis*, *Orthisina*, *Strophomena*, *Leptæna*, and *Davidsonia*, of which the first four only are sufficiently abundant to need notice here.

In the genus *Orthis* the valves are articulated by teeth and sockets, and usually are more or less transversely oblong (fig. 153). There is a straight hinge-line, generally shorter than the width of the shell. Each valve has a hinge-area, notched in its centre by a triangular fissure through which the fibres of the peduncle were transmitted. The shell is often more or less flattened or depressed, and the surface may be smooth, but is more commonly ornamented with striæ, or furnished with well-marked longitudinal ribs. The species of the genus *Orthis* abound in the Silurian, Devonian, and Carboniferous periods, especially in the first of these; but the genus is not known to have survived the Carboniferous period.

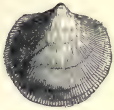


Fig. 155.—*Orthis elegantula*, Silurian.

In the genus *Orthisina* (fig. 156) the shell nearly resembles that of *Orthis;* but there is a double hinge-area, largest in the ventral valve, the central fissures of which are always covered by a convex deltidium; whereas in the latter genus they are open. In some species (as in *O. Verneuili*) the deltidium is perforated by a foramen under the beak of the ventral valve. The typical species of *Orthisina* are Silurian; but the genus is stated by Mr Davidson to range through the Devonian and Carboniferous into the Permian.

Fig. 156.—*Orthisina Verneuili*, Lower Silurian.

In *Strophomena* (fig. 157) the shell is depressed, generally semicircular, the hinge-line as long as the width of the shell, or longer. The surface may be smooth, but is most commonly striated or ribbed. There is a double

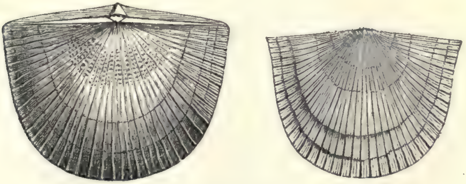


Fig. 157.—*Strophomena antiquata*, Silurian.

hinge-area, which is largest in the ventral valve. Each hinge-area has a median notch, which, in the ventral valve, is partially covered by a deltidium. The ventral valve may be

convex or concave, and the dorsal valve follows the curvature of the ventral valve. The species of the genus *Strophomena* are very abundant in the Silurian, Devonian, and Carboniferous formations, often attaining a large size; but they do not seem to have survived the close of the last-named period.

In the genus *Leptæna* are forms smaller than the *Strophomenæ*, but resembling them in many respects. The shell is more or less completely semicircular (fig. 158), with a double hinge-area, notched in the centre, the fissure in the ventral valve being partly covered by a deltidium. The valves articulate by teeth and sockets, and the surface is generally striated. The *Leptænæ* extend from the Silurian Rocks to the summit of the Lias, but are not known in any younger deposits.

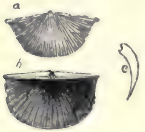


Fig. 158.—*Leptæna sericea.* *a* Ventral valve; *b* Dorsal valve; *c* Section of the shell. Silurian.

FAM. VII. PRODUCTIDÆ.—Animal unknown. Shell entirely free, or attached to submarine objects by the substance of the beak; valves either regularly articulated, or kept in place by muscular action alone. No calcified supports for the oral processes. The *Productidæ* are exclusively Palæozoic, and are especially characteristic of the Devonian, Carboniferous, and Permian deposits.

The two most important genera of the *Productidæ* are *Chonetes* and *Producta.* In the genus *Chonetes* (fig. 159) the shell is concavo-convex, transversely oblong, with a straight

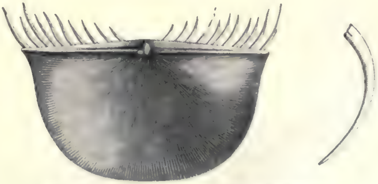


Fig. 159.—*Chonetes Dalmaniana*, Carboniferous.

hinge-line. The hinge-line is as wide as the shell, or the shell is eared. The ventral valve is convex, the dorsal concave, and both have a distinct hinge-area, with a central fissure, closed in the ventral valve by a pseudo-deltidium. The upper edge of the hinge-area of the ventral valve is furnished with a row of delicate, tubular spines. The species of

Chonetes are distributed in the Silurian, Devonian, and Carboniferous periods, but they are most abundant in the last of these.

In the genus *Producta* (fig. 160) the valves are not articulated by any apparatus of teeth and sockets, and the shell

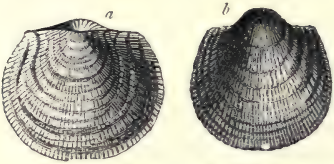


Fig. 160.—*Producta cora*, Carboniferous. *a* Dorsal valve; *b* Ventral valve. (After Dawson.)

would appear to have been free in the adult condition. The shell is generally transversely elongated, and is auriculate, or furnished with ear-like expansions. There is a straight hinge-line, usually shorter than the width of the shell. The hinge-area is rudimentary or wanting. The ventral valve is convex, the dorsal concave, following the curve of the former. The surface is ribbed or striated, and the ribs carry a greater or less number of longer or shorter tubular spines, which are especially abundant upon the auricular expansions. The species of *Producta* range from the Devonian to the Permian, but the genus is essentially and especially characteristic of the Carboniferous period.

FAM. VIII. CRANIADÆ.—Animal fixed to submarine objects by the substance of the ventral valve. Arms fleshy and

Fig. 161.—*Crania Ignabergensis*, Cretaceous.

spirally coiled. No hinge or articulating processes; upper or dorsal valve limpet-shaped (fig. 161). The family includes the

single genus *Crania*, which commenced in the Silurian period, and has continued to exist without interruption to the present day. The shell may be smooth, or striated with radiating ribs, sometimes with spines or foliaceous expansions. The ventral valve is the shallowest, and the shell is usually attached by a portion of its substance. The dorsal valve is more or less conical, and the valves are simply kept in apposition by muscular action.

FAM. IX. DISCINIDÆ.—Animal attached by means of a muscular peduncle passing through the ventral or lower valve, by means of a slit in its hinder portion or a circular foramen excavated in its substance. Arms fleshy. Valves unarticulated. The *Discinidæ* range from the Silurian period to the present day. The three most important genera are *Discina*, *Trematis*, and *Siphonotreta*.

In *Discina* (fig. 162) the shell is generally circular or orbicular in shape. The upper valve is limpet-shaped, smooth or

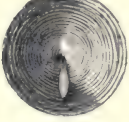


Fig. 162.—*Discina Circe*, Silurian.

Fig. 163.—*Discina Pelopea*, Silurian.

concentrically striated; the ventral valve is flat or partly convex, perforated by a longitudinal slit, which is placed in the middle of an oval depressed disc. The valves are not articulated to one another, but are kept together by muscular action alone. The species of the genus *Discina* range from the Silurian Rocks to the present day, seven species being now living.

In the genus *Trematis* both valves are more or less convex, and the general shape of the shell is more or less oval or suborbicular. The ventral valve is furnished with a slit for the passage of a peduncle of attachment. This genus seems to be exclusively Silurian.

Fig. 164.—*Siphonotreta verrucosa*, Silurian.

In the genus *Siphonotreta* (fig. 164) the shell is oval, inequivalve, with unarticulated valves. The beak of the ventral valve is perforated by a foramen which opens on its back, and communicates with the interior by a cylindrical tube. The surface of the shell is covered with

concentric lines of growth, and furnished with numerous delicate tubular spines, which, however, are rarely preserved. All the *Siphonotretæ* at present known belong to the Silurian period.

FAM. X. LINGULIDÆ.—Animal fixed by a muscular peduncle passing out between the beaks of the valves. Arms fleshy, not supported by calcified processes. Shell unarticulated, sub-equivalve, of a horny texture. The *Lingulidæ* range, in the person of *Lingula* itself, from the Cambrian period to the present day.

In the genus *Lingula* (fig. 165) the shell is oblong, compressed, the dorsal valve little smaller than the ventral. The

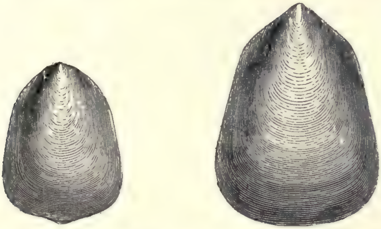


Fig. 165.—*Lingula Eva*, Lower Silurian. Dorsal and ventral valves. (After Billings.)

shell is oval, rounded, or satchel-shaped, tapering more or less towards the beaks. The surface is concentrically striated with lines of growth. The genus commences to be represented in the Cambrian Rocks, and has continued without interruption, and with no perceptible change, to the present day.

In *Obolus* the valves are orbicular, sub-equal, smooth, the ventral valve having a longitudinal furrow for the passage of

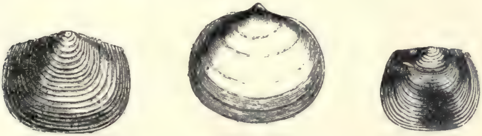


Fig. 166.—*Obolella cingulata*, Billings. Upper Cambrian.

fibres of attachment. The valves are unarticulated, and are maintained in apposition by muscular action. All the known species of *Obolus* are confined to the Silurian period, and are especially characteristic of the Lower Silurian period. The

genus *Obolella* (fig. 166) of Mr Billings is only separated from *Obolus* by certain internal characters. The little shells belonging to this genus sometimes occur in myriads in the Potsdam Group (Upper Cambrian) of North America.

CHAPTER XX.

LAMELLIBRANCHIATA.

THE *Lamellibranchiata* or Bivalve Shell-fish are distinguished by the fact that *the head is not distinct, and the mouth is destitute of any apparatus of teeth. The body is more or less completely protected in a bivalve shell, composed of two, usually symmetrical, pieces or valves. There are generally two leaf-like lamellar gills upon each side of the body.*

The Lamellibranchs include all the ordinary Bivalve Shell-fish, such as Oysters, Cockles, Mussels, and the like, and they are all either marine or inhabitants of fresh water.

Though they agree with the *Brachiopoda* in possessing a shell which is composed of two pieces or valves, there are, nevertheless, many points in which the shell of a Lamellibranch is distinguishable from that of a Brachiopod, irrespective of the great difference in the structure of the animal in each. The shell in the *Brachiopoda*, as we have seen, is rarely or never quite equivalve, and always has its two sides equally developed (equilateral); whilst the valves are placed antero-posteriorly as regards the animal, one in front and one behind, so that they are "dorsal" and "ventral." In the *Lamellibranchiata*, on the other hand, the two valves are usually of nearly equal size (equivalve), and are more developed on one side than on the other (inequilateral); whilst their position as regards the animal is always *lateral*, so that they are properly termed "right" and "left" valves, instead of "ventral" and "dorsal."

It is to be remembered, however, that many of the Bivalves, such as the Oysters, habitually lie on one side, in which case the valves, though really right and left, are called "upper" and "lower." It is to be borne in mind also that the two valves, especially in the attached Bivalves, may be very unsymmetrical, one valve being much larger or deeper than the other. Lastly, there are some cases in which the shell becomes very

nearly equilateral, the line drawn from the beaks to the base dividing the shell into two almost equal halves.

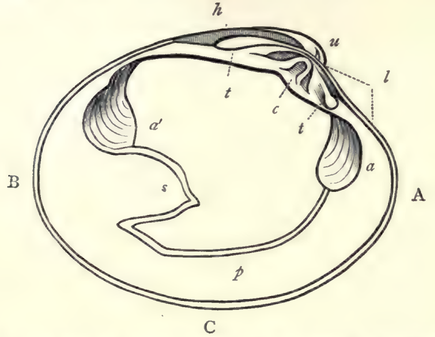


Fig. 167.—Left valve of *Cytherea chione* (after Woodward). A, Anterior margin; B, Posterior margin; C, Ventral margin or base; *u* Umbo; *h* Ligament; *l* Lunule; *c* Cardinal tooth; *t t* Lateral teeth; *a* Anterior adductor; *a'* Posterior adductor; *p* Pallial line; *s* Pallial sinus, caused by the retractor muscles of the siphons.

The following are the chief points to be noticed in connection with the shell of any Lamellibranch: Each valve of the shell may be regarded as essentially a hollow cone, the apex of which is turned more or less to one side; so that more of the shell is situated on one side of the apex than on the other. The apex of the valve is called the "umbo," or "beak" (fig. 167, *u*), and is always turned towards the mouth of the animal. Consequently the side of the shell towards which the umbones are turned is the "anterior" side, and it is usually the shortest half of the shell. The longer half of the shell, from which the umbones turn away, is called the "posterior" side, but in some cases this is equal to, or even shorter than, the anterior side. The side of the shell where the beaks are situated, and where the valves are united to one another, is called the "dorsal" side; and the opposite margin, along which the shell opens, is called the "ventral" side, or "base." The *length* of the shell is measured from its anterior to its posterior margin, and its *breadth* from the dorsal margin to the base.

At the dorsal margin the valves are united to one another for a shorter or longer distance, along a line which is called the "hinge-line." The union is effected in most shells by means of a series of parts which interlock with one another (the "teeth"), but these are sometimes absent, when the shell is

said to be "edentulous." Posterior to the umbones, in most bivalves, is another structure passing between the valves, which is called the "ligament," and which is usually composed of two parts, either distinct or combined with one another. These two parts are known as the "external ligament" (or the ligament proper), and the "cartilage," and they constitute the agency whereby the shell is opened; but one or other of them may be absent. The ligament proper is outside the shell, and consists of a band of horny fibres, passing from one valve to the other just *behind* the beak, in such a manner that it is put upon the stretch when the shell is closed. The cartilage, or internal ligament, is lodged between the hinge-lines of the two valves, generally in one or more "pits," or in special processes of the shell. It consists of elastic fibres placed perpendicularly between the surfaces by which it is contained, so that they are necessarily shortened and compressed when the valves are shut. To open the shell, therefore, it is simply necessary for the animal to relax the muscles which are provided for the closure of the valves, whereupon the elastic force of the ligament and cartilage is sufficient of itself to open the shell.

The hinge-line is mostly curved, but it may be quite straight. Generally the beaks are more or less contiguous, but they may be removed from one another to a greater or less distance, and in some anomalous forms they are not near one another at all. In the *Arcadæ* the two beaks are separated from one another by an oval or lozenge-shaped flat space or area. When teeth are present, they differ much in their form and arrangement. In some forms (fig. 167) the teeth are divisible into three sets —one group, of one or more teeth, placed immediately beneath the umbo, and known as the "cardinal teeth;" and two groups on either side of the preceding, termed the "lateral teeth." Sometimes there may be lateral teeth only; sometimes the cardinal teeth alone are present; and in some cases (*Arcadæ*) there is a row of similar and equal teeth.

In the interior of the shell of the Bivalves are found certain markings which are often of great importance to the palæontologist. The body is enclosed in an expansion of the dorsal integument, which constitutes the "mantle" or "pallium," whereby the shell is secreted. Towards its circumference the mantle is more or less completely united to the shell, leaving in its interior, when the soft parts are removed, a more or less distinctly impressed line, which is called the "pallial line" or "pallial impression" (fig. 168, *a*). In some of the Bivalves the two halves or "lobes" of the mantle are united at their margins, so that the animal is enveloped in an almost closed sac.

In these cases it is necessary that there should be orifices in the mantle-sac by which water can be admitted to the gills, and can be expelled again from the body. The margins or lips of these orifices are usually drawn out or extended into longer or shorter muscular tubes, which are termed the "siphons," and which may be either separate, or may be united to one another along one side. The Bivalves which possess these siphons are said to be "siphonate," and there are two leading modifications in the arrangement of these tubes. In the Siphonate Bivalves which spend their existence buried in sand or mud, as well as in many other cases, the siphons are long, and can be partially or entirely retracted within the shell by means of special muscles, called the "retractor-muscles of the siphons." In these cases, the pallial line does not run in an unbroken curve, but is deflected inwards posteriorly, so as to form an indentation or bay, which is termed the "pallial sinus" (fig. 168, 2). The presence, therefore, of *an indented pallial line shows that the animal possessed retractile siphons.* In other

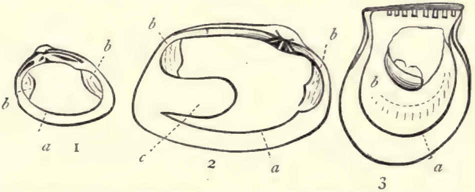


Fig. 168.—Shells of Lamellibranchiata. 1. *Cyclas amnica*, a dimyary shell with an entire pallial line. 2. *Tapes pullastra*, a dimyary shell with an indented pallial line. 3. *Perna ephippium*, a monomyary shell. (After Woodward.) *a* Pallial line; *b* Muscular impressions left by the adductors; *c* Siphonal impression.

Bivalves the respiratory siphons are of small size, and are destitute of retractor muscles, so that they cannot be withdrawn within the shell. In these cases the "pallial line," or the impression caused by the attachment of the muscular border of the mantle, is unbroken in its curvature, and presents no indentation (fig. 168, 1). In another group of the Bivalves there are no respiratory siphons at all, and the mantle-lobes are free, and are not united to one another at their edges. In these cases also, the pallial line is unbroken or "simple." When, therefore, we find a Bivalve shell in which *the pallial line is not indented* by a sinus, we know that the animal which inhabited the shell either *possessed no siphons, or that if siphons were present, they were small and not retractile.*

In accordance with these considerations, the *Lamellibranchiata* are divided into two sections, according as respiratory siphons are present or absent, and according to their nature when they exist.

SECTION A. ASIPHONIDA.—Animal without respiratory siphons; mantle-lobes free; the pallial line simple and not indented (*Integro-pallialia*).

This section comprises the families *Ostreidæ*, *Aviculidæ*, *Mytilidæ*, *Arcadæ*, *Trigoniadæ*, and *Unionidæ*.

SECTION B. SIPHONIDA.—Animal with respiratory siphons; mantle-lobes more or less united.

Two subdivisions are comprised in this section. In the first *the siphons are short, and the pallial line is simple* (*Integro-pallialia*); as is seen in the families *Chamidæ*, *Hippuritidæ*, *Tridacnidæ*, *Cardiadæ*, *Lucinidæ*, *Cycladidæ*, and *Cyprinidæ*.

The second subdivision (*Sinu-pallialia*) is distinguished by the possession of *long respiratory siphons*, and *a sinuated pallial line*, and it comprises the families *Veneridæ*, *Mactridæ*, *Tellinidæ*, *Solenidæ*, *Myacidæ*, *Anatinidæ*, *Gastrochænidæ*, and *Pholadidæ*.

Besides the impressions left by the muscular border of the mantle, and by the retractor muscles of the siphons, when these are present, there are other impressions caused by the insertion into the shell of the muscles by which the valves are brought together—the "adductor muscles." The number of adductor muscles never exceeds two, but there may be only one; and in accordance with this distinction the Bivalves have been divided into the two groups of the *Dimyaria* and *Monomyaria*. These divisions, however, are of small actual value. In most Bivalves there are two adductor muscles passing between the inner surfaces of the valves, one being placed anteriorly, in front of the mouth, whilst the other is situated posteriorly, in the neighbourhood of the vent. In the Monomyary Bivalves it is the posterior adductor which remains, and the anterior adductor is absent. The adductors leave distinct "muscular impressions," or scars, in the interior of the shell, so that it is easy in any given specimen to determine where there was only one adductor, or whether two were present (see fig. 168).

The habits of the *Lamellibranchiata* are very various. Some, such as the Oyster (*Ostrea*), and the Scallop (*Pecten*), habitually lie on one side, the lower valve being the deepest, and the foot being wanting, or rudimentary. Others, such as the Mussel (*Mytilus*), and the *Pinna*, are attached to some foreign object by an apparatus of threads, which is called the "byssus,"

and is secreted by a special gland. Others are fixed to some solid body by the substance of one of the valves. Many, such as the *Myas*, spend their existence sunk in the sand of the sea-shore or in the mud of estuaries. Others, as the *Pholades* and *Lithodomi*, bore holes in rock or wood, in which they live. Finally, many are permanently free and locomotive.

As regards the general *distribution in time* of the *Lamellibranchiata*, the class seems to have commenced in the Lower Silurian Rocks, and to have steadily increased up to the present day, when it seems to have attained its maximum, both as regards numbers and as regards variety of type. The recent Bivalves are also superior in organisation to those which have preceded them. In the Palæozoic and earlier Secondary deposits the Bivalves belong mainly to the group of the *Asiphonida*, in which there are no respiratory siphons. In the later Secondary and Tertiary Rocks, on the other hand, there is a predominance of *Siphonate* Bivalves, in which the mantle-lobes are united and there are respiratory siphons. Upon the whole, the *Lamellibranchiata* are sparingly represented in the Lower Silurian, more abundant in the Upper Silurian, reduced in numbers in the Devonian, very plentiful in the Carboniferous, scanty in the Permian and Trias, profusely represented in the Jurassic Rocks, and very abundant in the Cretaceous and Tertiary periods (Lobley). In the Carboniferous Rocks the family of the *Aviculidæ* is especially abundant. One very singular and aberrant family—viz., the *Hippuritidæ*—is exclusively confined to the Secondary period, and is not known to occur out of the limits of the Cretaceous formation. The *Veneridæ*, which are perhaps the most highly organised of the *Lamellibranchiata*, appear for the first time in the Oolitic Rocks, and, increasing in the Tertiary period, have culminated in the Recent period. The remains of *Lamellibranchiata* are very abundant in many formations, and are of great palæontological importance. It will therefore be well to review the families* of the class briefly, giving the leading characters, more important genera, and geological distribution of each.

SECTION A. ASIPHONIDA.

FAM. I. OSTREIDÆ.—Shell inequivalve, slightly inequilateral, free or attached; hinge usually edentulous. Ligament internal.

* In the following synoptical view of the *Lamellibranchiata*, the classification adopted in Woodward's admirable Manual of the Mollusca has been mainly followed.

Lobes of the mantle entirely separated; the foot small and byssiferous, or wanting. A single adductor muscle.

In the typical Oysters, forming the genus *Ostrea* (figs. 169,

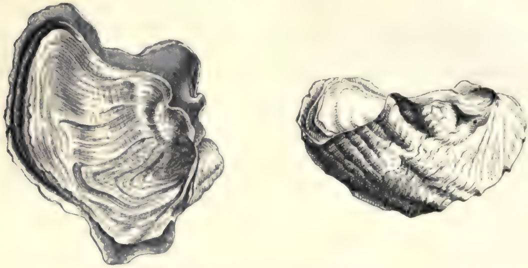


Fig. 169.—*Ostrea Couloni*, Lower Greensand.

170), the shell is irregular, and is attached by the left valve, which is also convex, and has a well-marked beak. The upper valve is generally flat or concave, and is the smallest of the

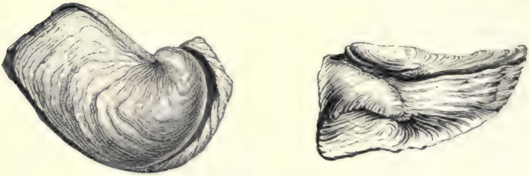


Fig. 170.—*Ostrea aquila*, Lower Greensand.

two valves. The hinge is toothless. Both valves may be more or less completely plain, and the upper one especially often is so. The lower valve, however, is commonly plaited, and both valves are sometimes thus ornamented, as in *Ostrea Marshii* of the Oolites (fig. 171).

In the sub-genus *Gryphæa* are included Oysters which were either quite free or very slightly attached. The left or lower valve (fig. 172) is much the largest, and has a very pronounced incurved beak, whilst the right valve is small and concave. In the sub-genus *Exogyra*, again, the beaks are "reversed"—that is to say, turned towards the posterior side of the shell. True Oysters commence to be represented in the Carboniferous

seas, abound in the Secondary and Tertiary periods, and are very plentiful at the present day. The sub-genera *Gryphæa* and *Exogyra* are exclusively Mesozoic, the former abounding

Fig. 171.—*Ostrea Marshii*, Oxford Clay (Middle Oolites).

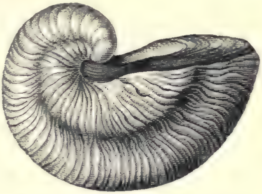


Fig. 172.—*Gryphæa incurva*, Lias.

especially in the lower portion of the Oolitic series, whilst the latter is chiefly characteristic of the later Oolitic and Cretaceous deposits.

In the *Anomiæ* the shell is thin and translucent, and is fixed to some solid body by a plug which passes through a hole or

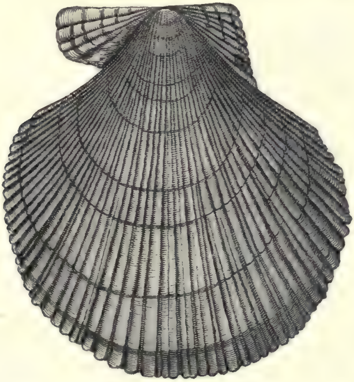


Fig. 173.—*Pecten Islandicus*, left valve. Post-Tertiary and Recent.

notch in the right valve. The typical fossil species are distributed from the Oolites upwards. The Oolitic genus *Placunopsis* is also related to *Anomia*.

The genus *Pecten* includes the Scallops (fig. 173), in which

the shell rests upon the right valve, and the beaks are furnished with ears. The anterior ears are usually the largest and most prominent, and the shell is generally furnished with ribs radiating from the umbos. The right valve is the deepest, and is notched below the anterior ear. Counting in its sub-genera, nearly five hundred species of the genus *Pecten* are known in the fossil state, commencing in the Devonian Rocks, and extending to the present day. The Palæozoic Pectens are distinguished from their successors in more modern rocks by having the posterior ears larger than the anterior; and they are therefore placed by M'Coy in a new genus, under the name of *Aviculopecten*. They are, however, usually regarded as belonging to the *Aviculidæ*.

In the genus *Lima* (or *Plagiostoma*) the shell is equivalve and free, whilst the beaks are separated from one another and are eared. The genus is represented by numerous species in the rocks of the Secondary period, and has survived to the present day.

In *Spondylus* (fig. 174) the shell is inequivalve, and is fixed by the right valve to some foreign body. The beaks are apart and

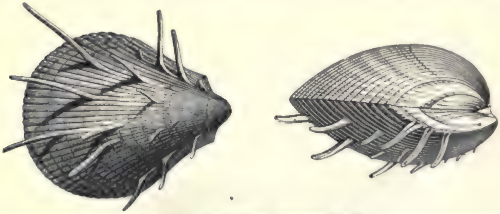


Fig. 174.—*Spondylus spinosus*, Chalk.

eared, and the shell is covered with spines, foliaceous expansions, or ribs radiating from the beak. The lower valve has a triangular hinge-area, and there are two teeth in each valve. The *Spondyli* seem to have commenced in the Cretaceous period, in which they are very abundant, and they have continued through the Tertiary period to the present day.

Lastly, the *Plicatulæ* (fig. 175) approach the *Spondyli* nearly, by having an inequivalve shell, which is attached by the right valve, and by having two hinge-teeth in each valve. The shell, however, is rarely eared, the hinge-area is obscure, and the valves are not spiny, though they may be plaited. The *Plicatulæ* extend from the Trias to the present day, and they abound to such an extent in parts of the Lower Greensand (Cretaceous),

as to have given rise to the name of "Argile à Plicatules" applied to the beds in question.

Fig. 175.—*Plicatula placunea*, Lower Greensand.

Fam. 2. Aviculidæ.—Shell inequivalve, very oblique, attached by a byssus; hinge nearly or quite edentulous. Mantle-lobes free; anterior adductor small, leaving its impression within the umbo; posterior adductor large and sub-central. Foot small.

Leaving out of consideration the genus *Aviculopecten*, which holds a dubious position, and has been already spoken of, the chief fossil genera of the *Aviculidæ* are *Avicula*, *Posidonomya*,

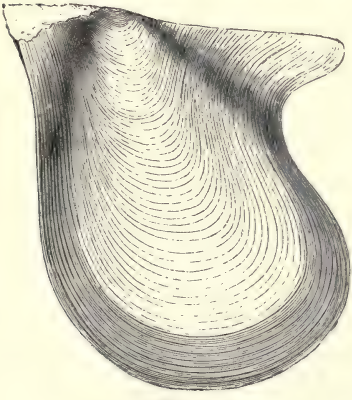


Fig. 176.—*Avicula demissa*, Lower Silurian.

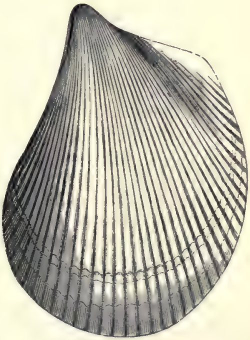
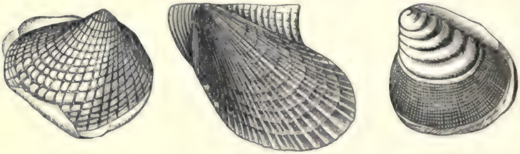


Fig. 177.—*Ambonychia radiata*, Lower Silurian.

Gervillia, *Perna*, *Inoceramus*, and *Pinna*. In the genus *Avicula* (fig. 176) the shell is oblique and very inequivalve. The right

valve has a notch under the anterior ear; and the hinge has one or two cardinal teeth, sometimes with an elongated posterior tooth. The true *Aviculæ* are represented by very numerous fossil species, extending from the Lower Silurian Rocks to the present day. Of the sub-genera of *Avicula*, the three most important fossil forms are *Ambonychia*, *Pterinea*, and *Cardiola*, the place of the last in this family being somewhat doubtful. In the *Ambonychiæ* (fig. 177) the valves are gibbous, nearly equal, and the anterior ear is almost obsolete. They extend from the Lower Silurian to the Carboniferous. The *Pterineas* (fig. 178) are very abundant in the Silurian Rocks, especially in the upper division of the series, and they extend to the Carboniferous Rocks.



A B C

Fig. 178.—A, *Pterinea sub-falcata*; B, *Cardiola interrupta*; C, *Cardiola fibrosa*. (After M'Coy and Salter.) Silurian.

They have a shell with large ears and very oblique, the hinge-area being long and straight. The *Cardiolæ* have an oblique, equivalve shell (fig. 178, B), radiately ribbed, with prominent beaks and a short hinge-area. They are mainly characteristic of the Upper Silurian Rocks, but they have been stated to occur in the Lower Silurian, and they are found in the Devonian.

The shells of the genus *Posidonomya* are very thin, concentrically striated, equivalve and earless. They extend from the Silurian to the Trias, but are especially characteristic of the Carboniferous Rocks. Many of the smaller shells referred to *Posidonomya* are undoubtedly referable to the Crustacean genus *Estheria*.

The genus *Gervillia* comprises a number of fossil shells, which range from the Carboniferous Rocks to the Chalk, and which are very like the true *Aviculæ*. The shell is elongated, the anterior ear small, and the posterior ear broad and winglike. Nearly allied to *Gervillia* is the genus *Perna*, which commenced in the Trias, and is represented in recent seas.

Nearly related to both *Gervillia* and *Perna* is the genus *Inoceramus* (figs. 179, 180), which is entirely confined to the Secondary period, and is mainly characteristic of the Creta-

ceous series. The shells of this genus are inequivalve, with radiating ribs or concentric furrows, and with prominent beaks. The hinge-line is long and straight, with numerous

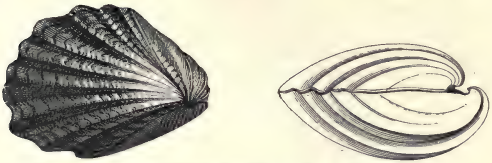


Fig. 179.—*Inoceramus sulcatus.* Gault (Cretaceous).

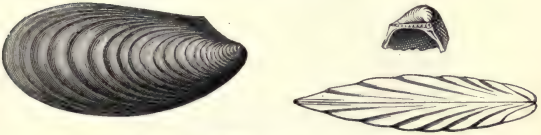


Fig. 180.—*Inoceramus problematicus.* Chalk.

cartilage-pits. Some of the *Inocerami* attain a length of two or three feet, and fragments of them are often found perforated by boring sponges.

The last genus of the *Aviculidæ* is *Pinna*, in which the shell is equivalve and wedge-shaped, and the beaks are placed quite on the anterior side of the shell. The *Pinnæ* seem to have commenced in the Devonian, but their existence prior to the Carboniferous period is a matter of some uncertainty. Many species are known in the Secondary and Tertiary Rocks, and the genus is well represented by living forms. The sub-genus *Trichites* is exclusively Oolitic, and the shells referred here sometimes attained an enormous size.

Fam. 3. Mytilidæ.—Shell equivalve; umbones *anterior;* hinge edentulous; anterior muscular impression small, posterior large. Shell attached by a byssus. Mantle-lobes united between the siphonal apertures. Foot cylindrical, grooved, and byssiferous. The chief fossil genera of the *Mytilidæ* are *Mytilus*, *Modiola*, *Lithodomus*, *Modiolopsis*, and *Orthonota*.

In the genus *Mytilus* are the true Mussels, in which the shell is wedge-shaped, and the beaks terminal. Numerous fossil forms are known, commencing in the Permian. The *Modiolæ*, or "Horse-mussels," have the beaks anterior, blunt, not pointed, the hinge edentulous, and the shell oblong.

More than one hundred fossil species have been described, commencing in the Lias, and extending to the present day. The Palæozoic *Modiolæ* are probably referable to different genera. The Date-shells (*Lithodomus*) form a sub-genus of *Modiola*, and are distinguished by their habit of forming perforations in rocks, in which they live. They appear to date from the Lower Oolitic Rocks, and are known to palæontologists by both their shells and their burrows.

The genus *Modiolopsis* (fig. 181), includes a number of Silurian shells, the true place of which is somewhat uncertain.

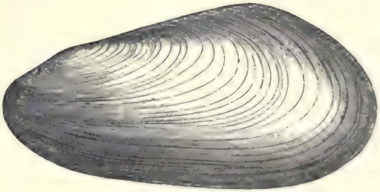


Fig. 181.—*Modiolopsis modiolaris.* Lower Silurian.

The shell is equivalve, very inequilateral, the beaks anterior, and the surface smooth, or marked by fine concentric lines of growth. The shell is thin, and its posterior end is considerably broader than the anterior.

The genus *Orthonota* likewise comprises a number of Silurian Bivalves, and is also in a somewhat doubtful position. The shell (fig. 182) is elongated, equivalve, very inequilateral, having the beaks placed close to its anterior end. The shell is thin, and its margins are parallel.

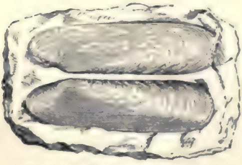


Fig. 182.—*Orthonota parallela.* Lower Silurian.

FAM. 4. ARCADÆ. — Shell equivalve; hinge long, with many comb-like teeth; muscular impressions nearly equal; mantle-lobes separated; foot large, bent, and deeply grooved. The most important fossil genera of this family are *Arca*, *Cucullæa*, *Pectunculus*, *Nucula*, *Ctenodonta*, *Cyrtodonta*, and *Leda*.

The Arks (*Arca*) have a straight hinge-line, with remote beaks, separated from one another by an oval or lozenge-

shaped ligamental area (fig. 183). The teeth are numerous and transverse, and the surface is generally strongly ribbed. Species of *Arca* have been described from the Lower Silurian Rocks upwards. It is probable, however, that the older Palæozoic forms referred here really belong to other genera, especially *Ctenodonta* and *Cyrtodonta*.

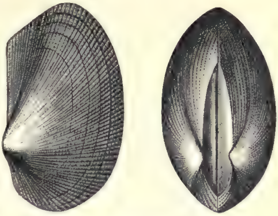


Fig. 183.—*Arca antiqua*. Permian.

In *Cucullæa* the shell is ventricose, and the hinge-teeth are few and oblique, and at each end of the hinge become parallel with the hinge-line. Species of this genus have been described from the Lower Silurian upwards.

The *Pectunculi* have a nearly round and equilateral shell, the beaks separated by a striated ligamental area, the hinge-line curved, and the hinge-teeth forming a semicircular row. *Pectunculus* is a comparatively modern genus, and does not seem to have come into existence before the Cretaceous period. Numerous species are known in the Tertiary Rocks.

The *Nuculæ* (fig. 184) have a trigonal shell, the beaks of which are reversed, and turned towards the posterior side of the shell, which is also the shortest side. The hinge has

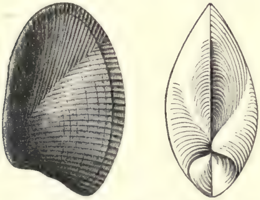


Fig. 184.—*Nucula bivirgata*. Gault.

a b


Fig. 185.—*Ctenodonta contracta*. Lower Silurian. *a* Interior of right valve; *b* Exterior of the same.

numerous teeth on each side of a central internal cartilage-pit. The Palæozoic shells referred to *Nucula* probably belong to other genera. Many species, however, are known from the Secondary and Tertiary Rocks.

The genera *Ctenodonta* and *Cucullella* are both nearly related to one another and to *Nucula*, and both are exclusively Palæozoic, and are mainly, if not entirely, Silurian. The *Ctenodontæ* (fig. 185) are extremely like *Nucula*, but are dis-

tinguished by having an *external* ligament. The posterior side of the shell is generally the shortest, but the reverse is sometimes the case.

The shells of the genus *Cyrtodonta* (*Palæarca* of Hall) are very inequilateral, the umbones being anterior (fig. 186). The

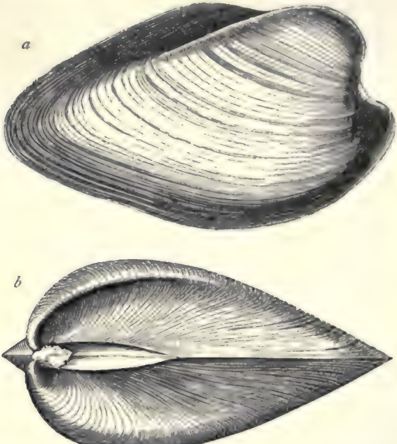


Fig. 186.—*Cyrtodonta Hindi* (Billings). Lower Silurian. *a* Dorsal view; *b* Side view.

hinge-area is undefined, and the surface generally smooth. There are a few (three) anterior cardinal teeth, and "two or three remote oblique posterior teeth parallel to the hinge-margin" (Salter). The species of *Cyrtodonta* appear to be exclusively confined to the Silurian and Devonian Rocks.

In the genus *Leda* the shell resembles that of *Nucula*, especially in having numerous teeth on either side of a central cartilage-pit. The shell, however, is oblong, rounded in front, and pointed behind. The occurrence of *Leda* in the Palæozoic period is dubious; but numerous species are known from the Secondary and Tertiary Rocks.

Fam. 5. Trigoniadæ.—Shell equivalve, trigonal; hinge-teeth few, diverging; umbones directed posteriorly. Mantle open; foot long and bent. The most important genera of this family are *Trigonia*, *Myophoria*, and *Axinus*.

In *Trigonia* (fig. 187) the shell is trigonal, with tubercles, radiating ribs, or concentric ridges. The hinge-teeth are two in one valve and three in the other. The *Trigoniæ* are

Fig. 187.—*Trigonia scabra.* Chalk.

essentially Mesozoic, being only known, in the fossil condition, as extending from the Trias to the Chalk. They are not known with certainty to be represented in the Tertiary Rocks at all; but the Australian seas have yielded some living forms.

The shells of the genus *Myophoria* have the umbones directed anteriorly, and are in most respects closely similar to *Trigonia.* They belong exclusively to the Triassic period.

The genus *Axinus* (*Schizodus*) is also nearly related to *Trigonia*, but the shell is thinner, and is smooth, and the posterior side is not so distinctly angular, but is marked by an oblique ridge. The shells of this genus extend from the Upper Silurian to the Trias, but are especially characteristic of the Permian Rocks.

FAM. 6. UNIONIDÆ.—Shell usually equivalve, with a large external ligament. Anterior hinge-teeth thick and striated; posterior laminar or wanting. Mantle-lobes united between the siphonal apertures. Foot very large, compressed, byssiferous in the fry. All the members of the *Unionidæ* are inhabitants of fresh water, and they are, therefore, not known as fossils except in fluviatile and lacustrine deposits. The only two fossil genera of the family are *Unio* and *Anodon.*

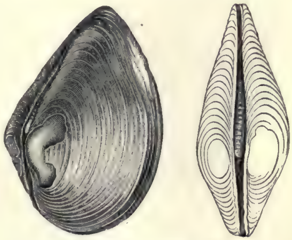


Fig. 188.—*Unio Waldensis.* Wealden (Lower Cretaceous).

In the genus *Unio* (fig. 188) the shell is oval or elongated, somewhat resembling that of a mussel (hence the name of River-mussels commonly

given to the *Unios*). The species of this genus appear to commence in the Lower Cretaceous Rocks, and they are very abundant at the present day. The beaks of fossil specimens are often deeply eroded, as are those of living forms.

The *Anodons* or Swan-mussels closely resemble the *Unios*, but the shell is edentulous. The earliest fossil forms occur in the Lower Tertiaries (Eocene).

Section B. Siphonida.

Sub-division I. Integropallialia.—Siphons short, pallial line simple.

Fam. 7. Chamidæ.—Shell inequivalve, attached. Hinge-teeth 2–1 (two in one valve and one in the other). Impressions of the adductors large. Mantle closed; pedal and siphonal orifices small and nearly equal. Foot very small. The most important fossil forms of this family belong to the genera *Chama*, *Diceras*, and *Requienia*.

In the genus *Chama* the shell is attached usually by the beak of the left valve, but sometimes by that of the right. The upper valve is the smallest, and both bear foliaceous expansions. The free valve carries one tooth which articulates with two teeth in the attached valve. The *Chamas* do not appear as fossils till we reach the Cretaceous Rocks, and they have continued to exist up to the present day.

In the remarkable genus *Diceras* (fig. 189), the shell is "sub-equivalve, attached by either umbo; beaks very prominent, spiral, furrowed externally by ligamental grooves; hinge very thick, teeth 2–1, prominent; muscular impressions bounded by long spiral ridges, sometimes obsolete" (Woodward). The species of *Diceras* are exclusively confined to the Middle Oolites. In this formation in the Alps they occur in such abundance as to give rise to the name of "Calcaire à Dicerates," applied to beds of the same age as the Coral Rag of Britain.

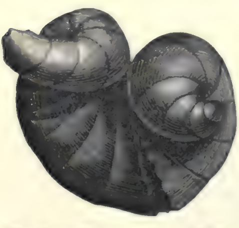


Fig. 189.—*Diceras arietina.* Middle Oolite.

The genus *Requienia* is exclusively confined to the Cretaceous period, and differs from *Diceras* chiefly in having a

very inequivalve shell, always attached by its left valve. The attached valve is the largest, and is spiral, whilst the free valve is small and sub-spiral.

FAM. 8. HIPPURITIDÆ (*Rudistes* of Lamarck).—"Shell inequivalve, unsymmetrical, thick, attached by the *right* umbo; umbones frequently camerated; structure and sculpturing of the valves dissimilar; ligament internal; hinge-teeth 1–2; adductor impressions two, large, those of the left valve on prominent apophyses; pallial line simple, sub-marginal."—(Woodward).

The *Hippuritidæ* are not only entirely extinct, but are exclusively confined to the Cretaceous Rocks, whence more than one hundred species have been described. All the members of this family were attached, and lived in beds like oysters. The two valves of the shell are always altogether unlike in sculpturing, appearance, shape, and size; and the cast of the interior of the shell is often extremely different to the form of the shell itself. About a hundred species of the family are known, all of which are Cretaceous, occurring in Britain, Southern Europe, the West Indies, North America, Algeria, and Egypt. Species of this family occur in such numbers in certain compact marbles in the south of Europe, of the age of the Lower Chalk, as to have given origin to the name of "Hippurite Limestones" applied to these strata.

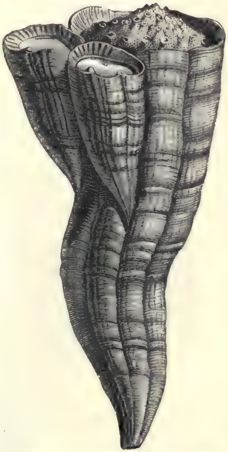


Fig. 190.—*Hippurites Toucasiana.* A large individual, with two smaller ones attached to it.

The *Hippuritidæ* have been especially studied by Dr S. P. Woodward, who makes the following remarks upon their structure and affinities:—"They are the most problematical of all fossils; there are no recent shells which can be supposed to belong to the same family; and the condition in which they usually occur has involved them in greater obscurity. The characters which determine their position amongst the ordinary Bivalves are the following:—

"1. The shell is composed of two distinct layers.

"2. They are essentially unsymmetrical and right-and-left valved.

"3. The sculpturing of the valves is dissimilar.

"4. There is evidence of a large internal ligament.

"5. The hinge-teeth are developed from the free valve.

"6. The muscular impressions are two only.

"7. There is a distinct pallial line.

"The outer layer of shell in the Hippurite and Radiolite consists of prismatic cellular structure; the prisms are perpendicular to the shell-laminæ, and subdivided often minutely. The cells appear to have been empty, like those of *Ostrea*. The inner layer which forms the hinge and lines the umbones, is sub-nacreous, and very rarely preserved. . . . . The inner shell-layer is seldom compact, its laminæ are extremely thin, and separated by intervals like the water-chambers of *Spondylus*. . . . . The chief peculiarity of the *Hippuritidæ* is the dissimilarity in the structure of the valves, but even this is deprived of much significance by its inconstancy. The free valve of *Hippurites* is perforated by radiating canals, which open round its inner margin, and communicate with the upper surface by numerous pores, as if to supply the interior with filtered water. . . . . In the closely allied genus *Radiolites* there is no trace of such canals, nor in *Caprotina*."

The shell of *Hippurites* (fig. 190) is inversely conical or cylindrical, and sometimes attains a length of a foot or more.

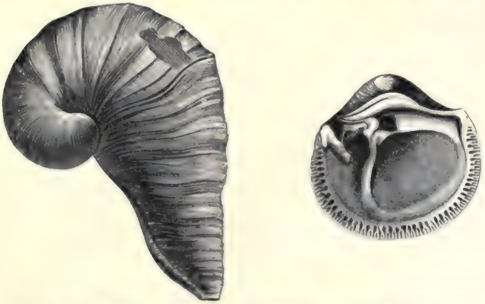


Fig. 191.—*Caprina Aguilloni*. The right-hand figure shows the interior of the left valve.

The shell is attached by the larger conical valve, and is closed by a small depressed free valve, with a central umbo. In

Radiolites the shell is inversely conical, bi-conical, or cylindrical, with dissimilar valves. The upper valve is sometimes flat, sometimes conical, and has a central umbo. In *Caprina* (fig. 191) the valves of the shell are dissimilar, the fixed valve being conical, whilst the free valve is oblique, or is spirally rolled. The free valve is thick, and is "perforated by one or more rows of flattened canals, radiating from the umbo, and opening all round the margin" (Woodward). The cavity of the free valve is sometimes chambered.

FAM. 9. TRIDACNIDÆ.—Shell equivalve; ligament external; muscular impressions blended, sub-central. Animal attached by a byssus, or free. Mantle-lobes extensively united; pedal aperture large; siphonal orifices surrounded by a thickened pallial border. Foot finger-like and byssiferous. The shell is truncated in front, the surface ribbed, and the margins toothed. The family contains the single genus *Tridacna*, which is not known to have come into existence before the period of the Miocene Tertiary.

FAM. 10. CARDIADÆ.—Shell equivalve, heart-shaped, with radiating ribs; cardinal teeth 2; lateral teeth 1–1 in each valve. Mantle open in front; siphons usually very short; foot large and sickle-shaped. The only two genera of this family are *Cardium* and *Conocardium*.

In *Cardium* are comprised the true Cockles, in which the shell is ventricose, the beaks pronounced, and placed nearly in the centre of the dorsal margin (fig. 192), the margins crenated,

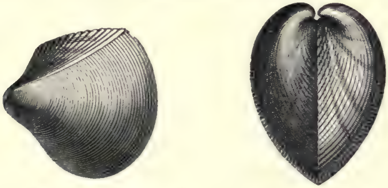


Fig. 192.—*Cardium Hillanum*. Upper Greensand.

and the pallial line more or less indented. It is doubtful if any true *Cardium* has been detected in the Silurian Rocks. With the Devonian, however, the genus begins to be well represented, and it has continued up to the present day, attaining its maximum in existing seas. The species figured above is separated from the true Cockles by having the posterior slope of the shell radiately striated, whilst the sides are concentrically furrowed.

The genus *Conocardium* comprises a number of Palæozoic shells, in which the anterior side is conical and gaping; whilst the posterior margin is truncated, and there is a longer or shorter siphonal tube placed near the beaks.

FAM. 11. LUCINIDÆ.—Shell orbicular, free; cardinal teeth 1 or 2; lateral teeth 1 – 1, or obsolete. Mantle-lobes open below, with one or two siphonal orifices behind; foot elongated, cylindrical, or strap-shaped. The most important fossil genera of the *Lucinidæ* are *Lucina* and *Corbis*. Nearly two hundred species of the former have been described, commencing with the Devonian; and about eighty species of the former are known, commencing with the Lias.

FAM. 12. CYCLADIDÆ.—Shell sub-orbicular, closed; hinge with cardinal and lateral teeth; ligament external. Mantle open in front; a single siphon, or two more or less united. Foot large, tongue-shaped. The genera *Cyclas* and *Cyrena* compose this family, and both are inhabitants of fresh water; though the latter not uncommonly frequents brackish water, and one species of the former has been described as marine.

In the *Cyclades* the shell is thin, and there are two hinge-teeth in one valve and one in the other. In *Cyclas* itself the shell is nearly equilateral, but in the sub-genus *Pisidium*, it is inequilateral, with the anterior side the longest. In *Cyrena* (fig. 193) the shell is thick, and there are three hinge-teeth in each valve. Both *Cyclas* and *Cyrena* seem to have come into existence at the commencement of the Cretaceous period (Wealden), and they are abundantly distributed through the Tertiary Rocks.

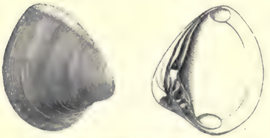


Fig. 193.—*Cyrena antiqua*. Eocene.

FAM. 13. CYPRINIDÆ.—Shell equivalve, closed; ligament external; cardinal teeth 1-3 in each valve, and usually a posterior tooth. Mantle-lobes united behind by a curtain pierced with two siphonal orifices. Foot thick and tongue-shaped. Of the genera of the *Cyprinidæ*, the more important fossil forms belong to *Cyprina*, *Astarte*, *Crassatella*, *Isocardia*, *Cardita*, and the extinct *Megalodon*, *Anthracosia*, *Hippopodium*, and *Pachyrisma*. Taken as a whole, the *Cyprinidæ* have passed their acme, and have begun to decline in numbers and importance.

Cyprina has a large, strong, oval shell, covered with a thick epidermis. Numerous fossil species are known, commencing in the Trias.

Astarte includes thick, generally concentrically-furrowed shells. Two hundred fossil species are known, commencing in the Lias.

Crassatella (fig. 194) comprises thick, solid, ventricose shells, attenuated posteriorly, and generally having a concen-

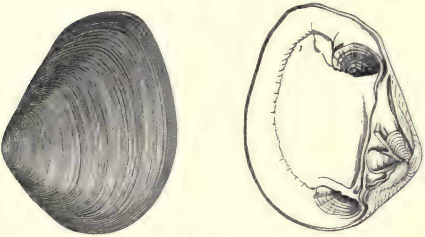


Fig. 194.—*Crassatella ponderosa*. Eocene Tertiary.

trically-furrowed surface. Unlike the two preceding genera, *Crassatella* has the ligament internal. The genus commences in the Cretaceous Rocks, is abundant in the Tertiaries, and is well represented at the present day.

In the Heart-cockles (*Isocardia*) the beaks are remote and sub-spiral, and the shell is heart-shaped. The *Isocardiæ* do not appear to have existed in the Palæozoic period, but commence in the Trias, are tolerably abundant in the Oolites and Cretaceous Rocks, decline in numbers in the Tertiaries, and are represented by a few forms in existing seas.

Cardita (fig. 195) includes Cockle-shaped shells, which have radiating ribs, an external ligament, and a toothed

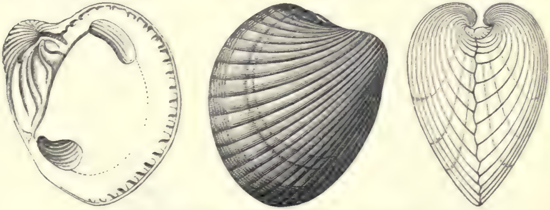


Fig. 195.—*Cardita planicosta*. Eocene Tertiary.

margin. The genus commences in the Trias, but attains its maximum in the Tertiary period, about a hundred species having been enumerated from rocks of this age.

Allied to *Cardita* is the extinct genus *Hippopodium*, well known by the thick and solid *H. ponderosum* of the Lias.

Pachyrisma is another extinct genus, in which the shell is also very thick and ponderous in its structure. It has large sub-spiral umbones, and is peculiar to the Great Oolite.

Megalodon is likewise extinct, and includes massive shells, with sub-spiral beaks and an external ligament. The genus is doubtfully represented in the Silurian and Carboniferous Rocks, and is characteristically Devonian.

Lastly may be mentioned the shells which are known as *Anthracosiæ*, which abound in parts of the Carboniferous series. These are nearly allied to the extinct genus *Cardinia*, if they do not actually belong to it. They are exclusively Palæozoic, and extend from the Upper Silurian to the Carboniferous; whereas *Cardinia* is very doubtfully represented in rocks older than the Lias.

Sub-division II. Sinupallialia.—Respiratory siphons large; pallial line indented.

FAM. 14. VENERIDÆ.—Shell regular, sub-orbicular or oblong; ligament external; hinge with usually three diverging teeth in each valve. Animal usually free and locomotive; mantle with a rather large anterior opening; siphons unequal, more or less united. Foot tongue-shaped, compressed, sometimes grooved and byssiferous. The *Veneridæ* are the most highly organised of the Bivalves, and comprise some of the most beautiful examples of the class. They commence in the Oolitic Rocks, are abundant in the Tertiaries, and have attained their maximum at the present day. All the more important fossil forms belong to the nearly-allied genera *Venus* and *Cytherea*. Both of these commenced their existence in the Oolites, the former being represented by about one hundred and fifty, the latter by nearly a hundred extinct forms.

FAM. 15. MACTRIDÆ.—Shell equivalve, trigonal; hinge with two diverging cardinal teeth, and usually with anterior and posterior lateral teeth. Mantle more or less open in front; siphons united, with fringed orifices; foot compressed. The only two genera of any importance as fossils are *Mactra* and *Lutraria*, both of which live buried in sand or mud. The *Mactræ* have a nearly equilateral shell, with a short pallial sinus, and an internal ligament contained in a triangular pit. They appear to have commenced in the Lias, and have attained their maximum at the present day. In *Lutraria* the shell is oblong and gaping at both ends, the pallial sinus is deep, and the internal ligament is supported by a prominent cartilage-plate. The genus is not known in rocks earlier than the Miocene Tertiary.

FAM. 16. TELLINIDÆ.—Shell free, usually equivalve and closed; cardinal teeth two at most, laterals 1–1, sometimes wanting. Ligament on the shortest side of the shell, sometimes internal. Mantle widely open in front. Siphons long and slender; foot tongue-shaped, compressed. Pallial sinus very large. The chief fossil genera are *Tellina*, *Psammobia*, and *Donax*. In *Tellina* the shell is very slightly inequivalve (fig. 196) with a prominent external ligament. More than a hundred fossil species are known, dating from the Oolitic period; but the genus has attained its maximum at the present day. In *Psammobia* the shell is oblong, compressed, and slightly gaping at both ends; whilst in *Donax* the shell is wedge-shaped, the front rounded and produced, the posterior side short. Both genera commence in the Eocene Tertiary, and are represented by numerous species at the present day.

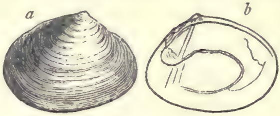


Fig. 196.—*Tellina proxima*, right valve. Post-Pliocene.

FAM. 17. SOLENIDÆ.—Shell elongated, gaping at both ends; ligament external; hinge-teeth usually 2–3. Siphons short and united (in the long-shelled genera), or longer and partly separate (in the genera with shorter shells). Foot very large and powerful. Gills prolonged into the branchial siphon. This family is of small geological importance. The Razor-shells (*Solen*) are represented by a few Tertiary forms, commencing in the Eocene; and the genera *Cultellus* and *Solecurtus* commence their existence in the Cretaceous Rocks.

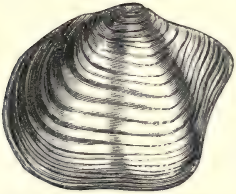


Fig. 197.—*Mya truncata*, Post-Pliocene and Recent.

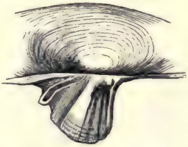


Fig. 198.—Portion of the hinge of *Mya arenaria*, showing the cartilage-process.

FAM. 18. MYACIDÆ.—Shell gaping posteriorly. Mantle almost entirely closed; siphons united, partly or wholly retrac-

tile. Foot very small. The more important genera of this family are *Mya*, *Corbula*, *Thetis*, *Panopæa*, and *Saxicava*.

In the Gapers (*Mya*), the shell is oblong, inequivalve, and gaping at both ends. The left valve is the smallest, and it carries an internal ligament supported upon a prominent cartilage-process (fig. 198). The Myas live buried vertically in sand or mud. They are not known to have existed before the period of the Middle Tertiary (Miocene), and almost all the fossil species are in existence at the present day.

In *Corbula* the shell is inequivalve, the left valve the smallest, and with a prominent cartilage-process; but the shell is gibbous, and does not gape at its ends, whilst the pallial sinus is small. Numerous fossil species are known, commencing in the Lower Oolites.

The genus *Thetis* is a small one, including thin, translucent, sub-orbicular shells, with an external ligament. A few species of the genus are known, commencing with the Lower Cretaceous Rocks.

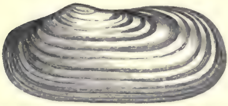


Fig. 199. — *Saxicava rugosa*, left valve. Post-Pliocene and Recent.

Panopæa resembles *Mya* in having a thick oblong shell, gaping at each end; but the shell is equivalve, and the ligament is external. Very numerous fossil species of this genus are known, commencing in the Lower Oolites.

Saxicava, as its name implies, includes shells which form burrows in rocks. The adult shell (fig. 199) is edentulous, equivalve, and oblong, gaping at the ends, and furnished with an external ligament. The genus seems to commence in the Eocene Tertiary, and has continued to the present day.

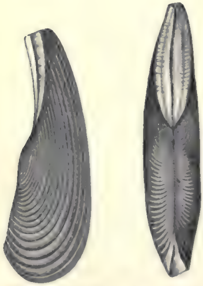


Fig. 200 — *Anatina spatulata*. Kimmeridge Clay (Upper Oolites).

Fam. 19. Anatinidæ. — Shell often inequivalve, with an external ligament. Mantle-lobes more or less united. Siphons long, more or less united. Foot small. The more abundant and important fossil genera of this family are *Anatina*, *Pholadomya*, and *Myacites*.

In the Lantern-shells (*Anatina*) the shell is oblong, gaping posteriorly, and having the beaks directed towards the posterior side (fig. 200). The hinge of each valve carries a spoon-shaped cartilage-process. The *Anatinæ* are doubtfully represented in the Devonian, and still more dubiously in the Silurian Rocks. They occur, however, abundantly in the Secondary Rocks, and are present in smaller numbers in the Tertiaries.

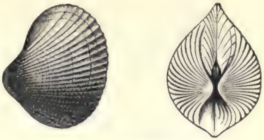


Fig. 201.—*Pholadomya æquivalvis*. Chalk.

The genus *Pholadomya* includes a large number of shells, which are equivalve, oblong, and gaping posteriorly (fig. 201). The shell is thin, ventricose, and adorned with radiating ribs on the sides. The ligament is external, and there is a large pallial sinus. The species of *Pholadomya* are very numerous in the Secondary Rocks, where they attain their maximum. They are much reduced in number in the Tertiaries, and are barely represented at the present day.

The genus *Myacites* has a gaping ventricose shell, with the umbones directed anteriorly, and the ligament external. They are known in the Palæozoic period, commencing in the Silurian; and they are represented in the earlier portion of the Secondary period; but they seem to have died out in the Chalk.

FAM. 20. GASTROCHÆNIDÆ.—Shell equivalve, gaping, with thin edentulous valves, sometimes cemented to a calcareous tube. Mantle-margins thick in front, united, with a small pedal aperture. Siphons very long, united. Foot finger-shaped. The members of the *Gastrochænidæ* burrow in mud or stone, and the only two fossil genera are *Gastrochæna* and *Clavagella*, the existence of *Aspergillum* in a fossil state being doubtful.

In *Gastrochæna* the shell is wedge-shaped, gaping in front and closed behind. The fossil species commence in the Inferior Oolite, and the genus is represented at the present day. In *Clavagella* (fig. 202) the shell is oblong, one of the valves being free, whilst the other forms part of a more or less elongated calcareous tube, which is often divided by a longitudinal partition and terminates in tubular openings. The fossil *Clavagellæ* commence in the Upper Greensand, and the genus is represented by several living species.

FAM. 21. PHOLADIDÆ.—Shell gaping at both ends, without

hinge or ligament, often with accessory valves. Animal club-shaped or worm-like, with a short truncated foot. Mantle closed in front; siphons long, united to near their extremities.

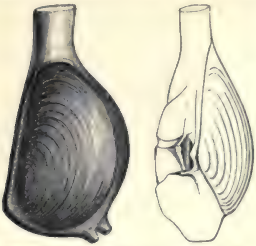


Fig. 202.—*Clavagella cretacea.* Chalk.

In the genus *Pholas* the shell is cylindrical or oval, the valves are edentulous, and there is no ligament or a rudimentary one. The pallial sinus is very deep, and the dorsal margin of the shell is protected by accessory valves. The *Pholades* inhabit burrows which they form for themselves in clay, peat, or rock. Many fossil species of the genus are known, commencing in the Jurassic Rocks.

In the genus *Teredo* the shell is "globular, open in front and behind, lodged at the inner extremity of a burrow partly or entirely lined by shell; valves three-lobed, concentrically striated, and with one transverse furrow; hinge-margins reflected in front, marked by the anterior muscular impressions; umbonal cavity with a long curved muscular process."—(Woodward.) Species of *Teredo* occasionally reach a very large size, and they are known in the fossil state both by their shells and by their burrows in wood. The genus seems to have commenced in the Lias, and is well represented at the present day.

CHAPTER XXI.

GASTEROPODA.

THE Gasteropods are *Molluscs in which the body is furnished with a distinct head, and the mouth is provided with a masticatory apparatus or "lingual ribbon." Locomotion is effected by means of a broad, horizontally-flattened, ventral disc—the "foot"—or by a vertically-flattened, fin-like modification of the same. The body is never included in a bivalve shell; and may be naked. Usually, however, there is a "univalve" shell, or in some cases a "multivalve" shell.*

This class includes all those Molluscous animals which are

commonly known as "Univalves," such as Land-snails, Sea-snails, Whelks, Limpets, &c. In the Chitons, however, the shell is composed of eight pieces ("multivalve"); and in the Slugs, the shell is minute and is completely concealed in the mantle; whilst in the Sea-slugs and Sea-lemons the animal is "naked," and is destitute of a shell.

In their habits the Gasteropods show great differences, most of them being free and locomotive, though some are sedentary. The typical forms move about more or less actively by the successive contractions and expansions of a muscular organ developed upon the ventral surface of the body and known as the "foot." In many cases the posterior portion of the foot secretes a calcareous, horny, or fibrous plate,

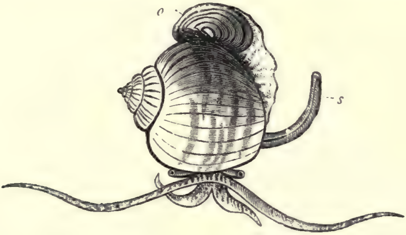


Fig. 203.—*Ampullaria canaliculata*, one of the Apple-shells. *o* Operculum; *s* Respiratory siphon.

which is called the "operculum" (fig. 203, *o*), and which serves to close the aperture of the shell when the animal is retracted within it. Lastly, in one aberrant group of the Gasteropods (*Heteropoda*) the animal is fitted for swimming in the open ocean, by the conversion of the "foot" into a vertically-flattened fin.

The respiratory process in the Gasteropods differs considerably in different cases; and the class may be divided into two principal sections, according as the animal is fitted for breathing air directly or through the medium of water. The air-breathing Gasteropods are known as the *Pulmonata* or *Pulmonifera*, and comprise forms which either live on land (Snails, Slugs, &c.), or which inhabit fresh water (Pond-snails, &c.) The water-breathing Gasteropods are mostly provided with distinct gills or "branchiæ," and they form the section of the *Branchifera*. They are mostly inhabitants of the sea; but some of them inhabit fresh water.

Shell of the Gasteropoda.—The shell of the Gasteropoda is composed either of a single piece (univalve), or of a number of plates succeeding one another from before backwards (multivalve). The univalve shell is to be regarded as essentially a cone, the apex of which is more or less oblique. In the simplest form of the shell the conical shape is retained without any alteration, as is seen in the common Limpet (*Patella*). In the great majority of cases, however, the cone is considerably elongated, so as to form a tube, which may retain this shape (as in *Dentalium*), but is usually coiled up into a spiral. The "spiral univalve" (fig. 205) may, in fact, be looked upon as the typical form of the shell in the *Gasteropoda*. In some cases the coils of the shell—termed technically the "whorls"—are hardly in contact with one another (as in *Vermetus*). More commonly the whorls are in contact, and are so amalgamated that the inner side of each convolution is formed by the pre-existing whorl. In some cases the whorls of the shell are coiled round a central axis *in the same plane*, when the shell is said to be "discoidal" (as in the common fresh-water shell *Planorbis*). In most cases, however, the whorls are wound round an axis in an oblique manner, a true spiral being formed, and the shell becoming "turreted," "trochoid," "turbinated," &c. This last form (fig. 204) is the one which may be looked

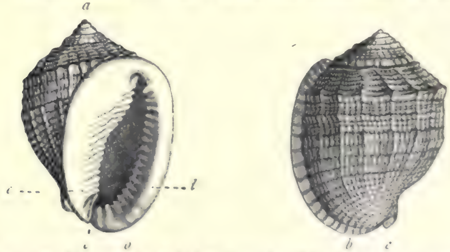


Fig. 204.—*Cassis cancellata*, a Spiral Gasteropod. *a* "Spire," placed at the posterior end of the shell; *b* "Mouth," placed at the anterior end of the shell; *c* Inner or columellar lip; *d* Outer lip; *e* Notch for the passage of a respiratory siphon.

upon as most characteristic of the Gasteropods, the shell being composed of a number of whorls passing obliquely round a central axis or "columella," having the embryonic shell or "nucleus" at its apex, and having the mouth or "aperture" of the shell placed at the extremity of the last and largest of the whorls, termed the "body-whorl." The lines or grooves formed by the junction of the whorls are termed the "sutures,"

and the whorls above the body-whorl constitute the "spire" of the shell. The axis of the shell (columella) round which the whorls are coiled is usually solid, when the shell is said to be "imperforate;" but it is sometimes hollow, when the shell is said to be "perforated," and the aperture of the axis near the mouth of the shell is called the "umbilicus." The margin of the "aperture" of the shell is termed the "peristome," and is composed of an outer and inner lip (fig. 204), of which the former is often expanded or fringed with spines. When these expansions or fringes are periodically formed, the place of the mouth of the shell at different stages of its growth is marked by ridges or rows of spines, which cross the whorls, and are called "varices." The animal withdraws into its shell by a retractor muscle, which passes into the foot, or is attached to the operculum; its scar or impression being placed, in the spiral univalves, upon the columella.

Fig. 205.—*Scalaria Grœnlandica*, a Holostomatous Univalve. Post-Pliocene.

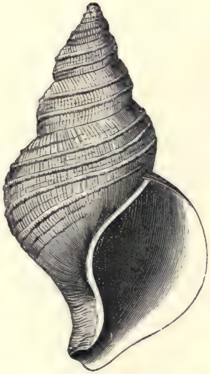


Fig. 206.—*Fusus tornatus*, a Siphonostomatous Univalve. Post-Pliocene.

In the multivalve Gasteropods, the shell is composed of eight transverse imbricated plates, which succeed one another from before backwards, and are embedded in the leathery or fibrous border of the mantle, which may be plain, or may be beset with bristles, spines, or scales.

In the marine Univalves two important variations exist in the form of the mouth of the shell. In one group (fig. 205)

the mouth of the shell is unbroken or "entire," not having any notch or indentation of its margin. The shells in which the mouth has this form are termed "holostomatous;" and for the most part they belong to Gasteropods which are phytophagous, or live upon vegetable food. The possession, however, of a holostomatous shell in reality simply proves that the animal had no respiratory "siphons," or tubes formed by the folding of the mantle. In a second group the aperture of the shell (fig. 206) is notched in front; and the shell is said to be "siphonostomatous." There may be a posterior notch as well as the anterior one, and one or both of these notches may be produced into longer or shorter canals. The Siphonostomatous Univalves are mainly carnivorous in their habits; but the notched mouth does not necessarily indicate the nature of the food. The possession of a Siphonostomatous shell, on the contrary, merely indicates that the animal possessed tubular inflections of the mantle, or "respiratory siphons," by which the water is conveyed to and from the gills.

Divisions of the Gasteropoda.—The following table shows the chief divisions of the *Gasteropoda*:—

Table of the Gasteropoda.

Section A. Branchifera.—Respiration aquatic, by the walls of the mantle-cavity or by gills.

Order I. Prosobranchiata.—The branchiæ situated (*proson*) in advance of the heart.

Division a. Siphonostomata.—Margin of the shell-aperture notched or produced into a canal. This division comprises the families of the *Strombidæ* (Wing-shells), *Muricidæ*, *Buccinidæ* (Whelks), *Conidæ* (Cones), *Volutidæ* (Volutes), and *Cypræidæ* (Cowries).

Division b. Holostomata.—Margin of the shell-aperture "entire," rarely notched or produced into a canal. This division includes the families of the *Naticidæ*, *Pyramidellidæ*, *Cerithiadæ*, *Melaniadæ*, *Turritellidæ*, *Littorinidæ* (Periwinkles), *Paludinidæ* (River-snails), *Neritidæ*, *Turbinidæ* (Top-shells), *Haliotidæ*, *Fissurellidæ* (Keyhole-limpets), *Calyptræidæ* (Bonnet-limpets), *Patellidæ* (Limpets), *Dentalidæ* (Tooth-shells), and *Chitonidæ*.

Order II. Opisthobranchiata.—Branchiæ placed towards the rear (*opisthen*) of the body.

Division a. Tectibranchiata.—Branchiæ covered by the shell or mantle. A shell in most. Sexes united. The division includes the families of the *Tornatellidæ*, *Bullidæ* (Bubble-shells), *Aplysiadæ* (Sea-hares), *Pleurobranchiadæ*, and *Phyllidiadæ*.

Division b. Nudibranchiata.—Animal destitute of a shell in the adult condition. Branchiæ external, on the back or sides of the body. This division includes the various naked Gasteropods commonly known as Sea-lemons and Sea-slugs.

Order III. Nucleobranchiata, or Heteropoda.—Shell present or absent. Animal free-swimming and oceanic, with a fin-like

tail or flattened ventral fin. This order includes the two families of the *Firolidæ* and *Atlantidæ*.

SECTION B. PULMONIFERA.—Respiration aerial, by means of a pulmonary chamber.

ORDER IV. INOPERCULATA.—Shell not provided with an operculum. This order comprises the families of the *Helicidæ* (Land-snails), *Limacidæ* (Slugs), *Oncidiadæ*, *Limnæidæ* (Pond-snails), and *Auriculidæ*.

ORDER V. OPERCULATA.—Shell provided with an operculum. In this order are the families *Cyclostomidæ* and *Aciculidæ*.

Distribution of the Gasteropoda in time.—As regards the general distribution of the Gasteropods in past time, all the families of the *Prosobranchiata* are known by fossil representatives. Of the *Opisthobranchiata* the Tectibranchiate section is tolerably well represented in past time; but the section of the *Nudibranchiata*, from the total absence of the shell, is not known at all in the fossil condition. Both families of the *Heteropoda* are represented by fossil forms. The Pulmonate Gasteropods, from the fact that they either live on land or inhabit fresh water, are necessarily not so fully represented in past time as are the Branchiate Gasteropods. Still, nearly all the families of the air-breathing Univalves have fossil representatives.

Taken as a whole, the *Gasteropoda* are represented in past time from the Upper Cambrian Rocks upwards. Of the *Branchifera*, the *Holostomata* are more abundant in the Palæozoic period; and the *Siphonostomata* predominate more in the Secondary and Tertiary periods, attaining their maximum at the present day. The place of the carnivorous *Siphonostomata* in the Palæozoic seas appears to have been filled by the Tetrabranchiate Cephalopods. The Branchiate Gasteropods of fresh water are chiefly represented as fossils by the genera *Paludina*, *Valvata*, and *Ampullaria*.

The *Heteropoda* are likewise of very ancient origin, having commenced their existence in the Upper Cambrian deposits. The genera *Bellerophon*, *Porcellia*, *Cyrtolites*, and *Maclurea*, are exclusively Palæozoic; *Bellerophina* is found in the Gault (Secondary), and *Carinaria* has been detected in the Tertiaries.

The Pulmonate *Gasteropoda*, as was to be anticipated, are not found abundantly as fossils, occurring chiefly in lacustrine and estuarine deposits, in which the genera *Limnæa*, *Physa*, *Ancylus*, &c., are amongst those most commonly represented. These, however, are entirely Mesozoic and Kainozoic. In the Palæozoic period the sole known representatives of the

Pulmonifera are the *Pupa vetusta* and *Zonites priscus* of the Carboniferous Rocks.

In the following* are given the characters of those families of the *Gasteropoda* which occur in the fossil state, with the leading genera of each family and their range in time.

SECTION A. BRANCHIFERA.—Respiration aquatic, generally by gills.

ORDER I. PROSOBRANCHIATA.—*Gills situated in advance of the heart.*

Division a. Siphonostomata.—Mouth of the shell notched, or produced into a canal.

FAM. 1. STROMBIDÆ.—Shell with an expanded lip, deeply notched near the canal. Operculum claw-shaped. Foot narrow, adapted for leaping. All the existing genera of the *Strombidæ* are represented in the fossil state, but the family does not seem to have come into existence before the Jurassic period, and it attained its maximum in the Tertiary period.

Fig. 207.—*Pteroceras oceani.* Neocomian.

The genus *Strombus* has a shell with a short spire, a long aperture, and an expanded outer lip, there being a posterior as well as an anterior notch. The Strombs are represented in

* In the characters of the families of the *Gasteropoda*, as in those of the *Lamellibranchiata*, Woodward's 'Manual of the Mollusca' has been mainly followed.

the Cretaceous and Tertiary Rocks; but they attain their maximum in existing seas.

The Scorpion-shells form the genus *Pteroceras* (fig. 207), in which the shell of the adult has its outer lip furnished with long claws, one of which forms a posterior canal close to the spire. Many fossil species are known, commencing in the Lias.

In the genus *Rostellaria*, the spire is long, and has the posterior canal running up it. Many fossil species are known, commencing in the Cretaceous Rocks. The outer lip is always expanded, and in some forms is enormously so. Lastly, the genus *Seraphs* comprises smooth shells, with a short or obsolete spire, a thin outer lip, and a long narrow mouth. The fossil species date from the Eocene Tertiary.

FAM. 2. MURICIDÆ.—Shell with a straight anterior canal, the aperture entire posteriorly. Foot broad. The *Muricidæ* are essentially characteristic of the Tertiary and Recent periods. They commence, however, in the Jurassic Rocks, in some doubtful examples, and they are certainly represented in the Cretaceous Rocks by not a few forms.

In the genus *Murex* the canal is often very long, and may be partially closed; the shell is ornamented with longitudinal ridges or rows of spines (*varices*), and the aperture is rounded.

In the nearly-related *Typhis* (fig. 208) there are tubular spines between the varices, and the last of these lodges the posterior siphon. Both *Murex* and *Typhis* commence in the Eocene Tertiary, and have attained their maximum in existing seas.

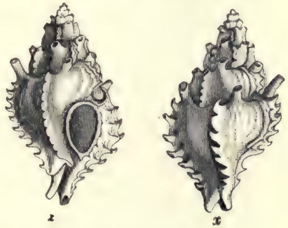


Fig. 208.—*Typhis tubifer*. Eocene Tertiary.

Pisania commences to be represented in the Eocene, as do the genera *Ranella*, *Triton*, and *Cancellaria*. *Fasciolaria* and *Pyrula* commence their existence in the Cretaceous Rocks; and *Turbinella* and *Trichotropis* do not make their appearance till the Miocene. Lastly, the great genus *Fusus*, distinguished by the spindle-shaped, many-whorled shell, and long straight canal (fig. 209), appears to have its commencement in the Oolites. *Fusi* become very numerous towards the close of the Cretaceous period, and they are very plentiful in the Tertiaries. One of the common fossils

of the Red Crag (Newer Pliocene) is the reversed shell, *Fusus contrarius*, which is now known to exist in the living state as well.

Fig. 209.—*Fusus Necomiensis.* Lower Greensand.

Fig. 210.—*Buccinum undatum* (*var.*) Post-Pliocene and Recent.

FAM. 3. BUCCINIDÆ.—Shell notched anteriorly, or with the canal reflected, producing a kind of varix on the front of the shell. With the exception of the extinct genus *Purpurina* of the Lower Oolites, and some species of *Buccinum* in the Cretaceous Rocks, the family of the *Buccinidæ* is exclusively confined to the Tertiary and Recent periods. The two great families, therefore, of the *Muricidæ* and *Buccinidæ* are essentially characteristic of the later periods of the earth's history. The most important fossil genera of the *Buccinidæ* are *Buccinum*, *Terebra*, *Nassa*, *Purpura*, *Cassis*, and *Oliva*.

The Whelks form the genus *Buccinum* (fig. 210), distinguished by the ventricose body-whorl, large aperture, and short reflected canal. Some few species of *Buccinum* are found in the Upper Cretaceous Rocks; but the genus is essentially Tertiary and Recent.

Terebra comprises the Auger-shells, distinguished from the Whelks by their long, pointed shells, consisting of many whorls, and having a small mouth. They commence in the Eocene Tertiary. The Dog-whelks (*Nassa*) also commence in the Eocene, and are distinguished from the Whelks chiefly by having the columellar lip expanded and callous, with a tooth near the anterior canal. The shells of the genus *Purpura*

have a short spire and wide aperture, with an expanded and flattened inner lip. They commence in the Miocene Tertiary. The Helmet-shells (*Cassis*) begin in the Eocene, and are distinguished by their short spire, large body-whorl, long aperture, recurved canal, and expanded inner lip. Lastly, the Olives (*Oliva*) and Rice-shells (*Olivella*) are characterised by their cylindrical polished shell, with a short spire, a long narrow aperture, notched in front, and obliquely-striated columella. The living Olives are tropical and sub-tropical in their distribution, and the fossil species commence in the Eocene Tertiary.

FAM. 4. CONIDÆ.—Shell inversely conical, with a long narrow aperture, the outer lip notched at or near the suture. The *Conidæ* commence in the Cretaceous Rocks, abound in the Tertiaries, and attain their maximum at the present day.

The true Cones form the genus *Conus*, and are distinguished by their short spire and regularly conical shell, of which the outer lip is notched near the suture. The Cones are represented in the Chalk, but are mainly Tertiary and Recent. The genus *Pleurotoma* is distinguished by a spindle-shaped shell, with a long spire, the outer lip having a deep slit near the suture. The genus commences in the Chalk, and has an enormous development in the Tertiaries, from which nearly three hundred species are known. The maximum, however, is attained in existing seas, in which there are very numerous species.

Fig. 211.—*Voluta elongata.* Chalk.

FAM. 5. VOLUTIDÆ.—Shell turreted or convolute, the aperture notched in front; the columella obliquely plaited. No operculum. Foot very large; mantle often reflected over the shell. The living members of the *Volutidæ* are chiefly inhabitants of warm seas, and are often remarkable for their brilliant colours. The family does not appear to have existed till towards the later portion of the Cretaceous period; but it is abundantly represented in the Tertiaries, and attains its maximum in existing seas. The most important genera are *Voluta* and *Mitra*.

The true Volutes form the genus *Voluta* (fig. 211), charac-

terised by the short spire, large, deeply-notched aperture, and columella with several plaits. Species of *Voluta* occur in the Cretaceous period, but the genus is mainly Tertiary and Recent.

In the genus *Mitra* the shell is spindle-shaped, with a long spire, and small mouth. The *Mitræ* commence in the Cretaceous period, but the fossil species are mainly distributed through the Tertiary formations.

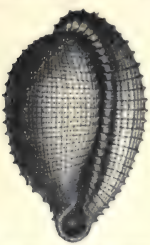


Fig. 212.—*Cypræa elegans.* Eocene Tertiary.

FAM. 6. CYPRÆIDÆ.—Shell convolute, enamelled; spire concealed; aperture narrow, channelled at each end. Outer lip thin in the young shell, but thickened and inflected in the adult. Foot broad; mantle forming lobes which meet over the back of the shell. The only important genus of this family is that of *Cypræa* (fig. 212), comprising the numerous and well-known living shells which are commonly called Cowries. The *Cypræœ* are mainly, but not exclusively, inhabitants of warm seas, and they attain their highest development between the tropics. The fossil species date from the Cretaceous period, and abound in the Tertiaries.

The shell of the Cowries in the young state is furnished with a prominent spire, and has a thin outer lip. In the adult state (fig. 212) the spire is completely concealed within the shell, the entire surface is generally covered with shining enamel, the inner lip is crenulated, and the outer lip is thickened, inflected, and crenulated. The small Cowries of which *Cypræa Europœa* is the type, are not known as occurring in the fossil condition.

Division b. Holostomata.—Margin of the shell-aperture "entire," rarely notched or produced into a canal.

FAM. 7. NATICIDÆ.—Shell globular, of few whorls, with a small spire; outer lip acute; inner lip (pillar) often callous. Foot very large; mantle-lobes hiding more or less of the shell. This family is stated to commence in the Upper Silurian Rocks; but there is more or less uncertainty as to the true affinities of the Palæozoic fossils which are referred here. The most important fossil genus is *Natica* itself.

The shell in *Natica* (fig. 213) is thick, smooth, and polished, often with coloured markings. The inner lip is callous, and the shell is umbilicated. Fossil *Naticæ* have been described from the Upper Silurian, Devonian, Carboniferous, and Permian Rocks; and they are very abundant in all the Secondary

and Tertiary formations. The sub-genus *Naticopsis* is Carboniferous, *Naticella* is Triassic, and *Globulus* is found in the Eocene.

FAM. 8. PYRAMIDELLIDÆ.—Shell turreted, with a small aperture; sometimes with one or more prominent plaits on the columella. Operculum horny and imbricated. The *Pyramidellidæ* commence in the Lower Silurian Rocks, and appear to be on the decline at the present day. The chief fossil forms belong to the genera *Chemnitzia*, *Eulima*, *Loxonema*, and *Macrocheilus*.

Chemnitzia includes a number of slender, turreted, many-whorled shells, with plaited whorls, and a simple aperture. The genus appears to commence in the Permian Rocks, and whilst more than one hundred and fifty fossil species are known, the number of living forms is very small. Many of the shells, however, included under this head, are of very doubtful affinities.

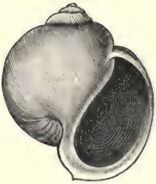


Fig. 213.—*Natica clausa*. Post-Pliocene.

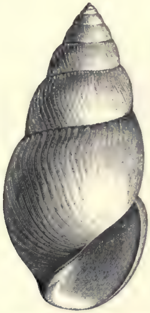


Fig. 214.—*Macrocheilus subcostatus*. Devonian.

Eulima includes small, polished, elongated shells, with level whorls and a reflected inner lip. *Eulimæ* are of doubtful occurrence in the Carboniferous Rocks, are sparingly represented in the Secondary Rocks, but are tolerably abundant in the Tertiaries.

The genera *Loxonema* and *Macrocheilus* (fig. 214), lastly, include Palæozoic shells, whose true place is in many cases uncertain. The former extends from the Lower Silurian to the Trias, but the latter is mainly, if not exclusively, confined to the Devonian and Carboniferous Rocks.

FAM. 9. CERITHIADÆ.—Shell spiral, turreted; aperture channelled in front, with a less distinct posterior canal. Lip generally expanded in the adult. Operculum horny and spiral. The *Cerithiadæ* are exclusively confined to the Secondary, Tertiary, and Recent periods, and are represented in the Tertiary Rocks by a vast number of forms. The most important fossil forms belong to the genera *Cerithium*, *Potamides*, *Nerinæa*, and *Aporrhais*, of which *Nerinæa* is extinct, and is exclusively confined to the Secondary period.

For all practical purposes *Cerithium* and *Potamides* may be considered together, as no strict line of demarcation can be drawn between the fossil forms. In both, the shell is turreted and many-whorled (fig. 215), with or without varices.

Fig. 215.—*Cerithium hexagonum.* Eocene Tertiary.

Fig. 216.—*Nerinæa bisulcata.* Chalk.

The aperture of the shell is small, with a tortuous anterior canal, and an expanded outer lip. Most of the living forms are inhabitants of fresh or brackish waters, and they are chiefly found in hot climates. The fossil forms, to the number of nearly five hundred, commence in the Trias, but they attain their maximum of development in the Eocene Tertiary.

In the genus *Nerinæa* (fig. 216), the shell is turreted, many-whorled, and nearly cylindrical. The columella carries continuous ridges, and similar ridges exist on the interior of the whorls, so that casts of the interior of the shell are often very unlike the form of the exterior. The aperture of the shell is channelled in front. The species of *Nerinæa* are exclusively Jurassic and Cretaceous, and are very numerous. One of the limestones of the Jura, believed to be of the age of the Coral Rag (Middle Oolite) of Britain, abounds to such an extent in these shells as to have gained the name of "Calcaire à Nérinées."

In the genus *Aporrhais*, lastly, the shell is turreted, and the outer lip of the adult is greatly expanded and lobed. The species of this genus are marine in their habits. A great many Jurassic and Cretaceous shells, generally referred at present to *Rostellaria*, probably belong really to *Aporrhais*; but the de-

termination of these fossils by the shells alone is attended with great difficulties.

FAM. 10. MELANIADÆ.—Shell spiral, turreted; aperture often channelled or notched in front; outer lip acute. Operculum horny and spiral. Many fossil shells have been referred to the *Melaniadæ*, but it is probable that most of these belong to the Palæozoic genus *Loxonema* and the Mesozoic *Chemnitzia*. The true *Melaniæ* do not appear to have commenced their existence till the Eocene Tertiary. All the living species inhabit fresh water, generally in the warmer parts of the world; and it is probable that all the fossil species occur only in fluviatile and lacustrine deposits.

FAM. 11. TURRITELLIDÆ.—Shell tubular or spiral, often turreted; upper part partitioned off; aperture simple. Operculum horny, many-whorled. Foot very short. Branchial plume single. The *Turritellidæ* are not known to have existed in the Palæozoic period; but they appear to commence about the middle of the Jurassic period, abounding in the Tertiaries, and attaining their maximum in existing seas. The chief fossil genera are *Turritella*, *Vermetus*, and *Scalaria*.

In *Turritella* (fig. 217) the shell is turreted. many-whorled, and spirally striated; the aperture is small and rounded, and the peristome thin. Species of *Turritella* have been described from the Palæozoic and older Mesozoic formations, but almost certainly belong to the genera *Murchisonia* and *Loxonema*. The genus is for the first time represented with certainty in the Lower Cretaceous Rocks (Neocomian), and many fossil species are found in the Tertiaries.

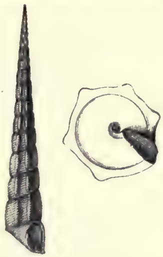


Fig. 217.—*Turritella angulata.* Neocomian.

The genus *Vermetus* comprises tubular shells, the chief interest of which is the strong resemblance which they show to the Annelidous genus *Serpula*. The shell is attached, and though regularly spiral when young, is always irregular in its growth when adult. The fossil species are best distinguished from *Serpula* by the fact that the tube is repeatedly partitioned off by calcareous septa, as the animal grows. It is, however, often a matter of extreme difficulty to determine whether a given specimen be a *Vermetus* or a *Serpula*. Fossil *Vermeti* are known from the Lower Cretaceous upwards.

The genus *Scalaria* comprises the Wentle-traps, in which

the shell is very like that of *Turritella*, but the whorls are ornamented with transverse ribs, and the peristome is continuous round the circular aperture (fig. 205). The *Scalariæ* commence in the Middle Oolites (Coral Rag), and attain their maximum in existing seas.

FAM. 12. LITTORINIDÆ.—Shell spiral, top-shaped, or depressed; aperture rounded and entire, operculum horny and pauci-spiral. The exact range of the *Littorinidæ* in time is uncertain, owing to the difficulty of determining the true affinities of many fossil Univalves. Several Palæozoic and Mesozoic shells have been referred to *Littorina*, and the genus *Rissoa* commences in the Permian. The family, however, is mainly characteristic of the Tertiary and Recent periods.

In the genus *Littorina* are the true Periwinkles, distinguished by their thick, generally top-shaped and pointed shells, of few whorls, and with an imperforate columella. The undoubted fossil species range from the Middle Tertiaries to the present day.

In the genus *Solarium* (fig. 218) the shell is much depressed; there is a large and deep umbilicus, running from the base to the apex of the shell, and the aperture of the shell is rhombic. Doubtful Secondary forms of this genus are known; but the undoubted species commence in the Eocene Tertiary. The genus *Phorus* also comprises shells, the true range of which is very uncertain. Undoubted species, however, date from the Cretaceous period. Lastly, in the genus *Rissoa* the shell is very small, pointed, and many-whorled, with a small round aperture surrounded by a continuous peristome. Many fossil species are known, commencing in the Permian Rocks, abounding in the Oolites, and being very abundant in the later Tertiaries.

Fig. 218.—*Solarium ornatum*. Gault (Upper Cretaceous).

FAM. 13. PALUDINIDÆ.—Shell conical or globular; aperture rounded and entire; operculum horny or shelly. The *Paludinidæ* are essentially inhabitants of fresh water; though they sometimes live in brackish, or even in salt water. As a matter of course, therefore, they are chiefly, if not exclusively, found as fossils in deposits which are believed to be fluviatile

or lacustrine in their origin. The three chief or only living genera are, *Paludina*, *Valvata*, and *Ampullaria*. The two former date from the Cretaceous period, the first possibly from the Jurassic, and both abound in the Wealden and in many Tertiary deposits. The existence of *Ampullariæ* in a fossil state is attended with considerable uncertainty, chiefly from the great difficulty, or impossibility, of separating them from species of the marine genus *Natica*.

FAM. 14. NERITIDÆ.—Shell thick, globular, with a very small spire; aperture semi-lunate, its columellar side expanded; outer lip acute. Operculum shelly, sub-spiral. The *Neritidæ* are not known as occurring in the Palæozoic Rocks, but are found from the Jurassic period onwards, attaining their maximum at the present day.

In the genus *Nerita* (fig. 219) the shell is thick, with a broad columella, the inner edge of which is straight and toothed.

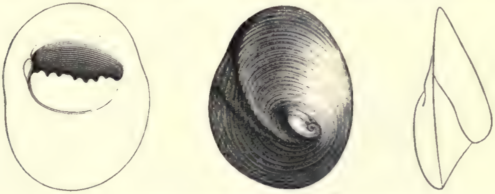


Fig. 219.—*Nerita Schemidelliana*. Eocene Tertiary.

The outer lip is thickened and often denticulated internally. The true Nerites are inhabitants of warm seas; and they date in past time from the Lias. The nearly-allied genus *Neritina* includes the so-called "fresh-water Nerites," which agree in most characters with *Nerita*, but inhabit fresh or brackish waters. The fossil species commence in the Eocene Tertiary. Lastly, the genus *Pileolus* comprises small limpet-shaped shells, with a semi-lunar aperture below. The only fossil species are from the Lower Oolites (Great Oolite).

FAM. 15. TURBINIDÆ.—Shell turbinated (top-shaped) or pyramidal, nacreous (*i.e.* pearly) inside. Operculum horny and multi-spiral, or calcareous and pauci-spiral. The family of the *Turbinidæ* has a very high antiquity, dating from the Lower Silurian; but many of the older shells referred to this family are of more or less doubtful affinities. The most important fossil genera are *Turbo*, *Trochus*, and *Euomphalus*.

In the genus *Turbo* (fig. 220) the shell is turbinated, with a

round base. The whorls are convex; the aperture is large and rounded; and the operculum is calcareous. A great number of fossil species of this genus have been described, commencing in the Lower Silurian; but there is considerable doubt as to the true position of many of the older forms.

Fig. 220.—*Turbo subcostatus.* Devonian.

In the genus *Trochus* the shell is pyramidal, with a nearly flat base; the aperture is oblique and rhombic in shape, and the operculum is horny. A great number of species of this genus, also, have been described, commencing in the Silurian Rocks. As in the case of *Turbo*, however, the affinities of many of the older forms are very problematical.

The genus *Euomphalus* (fig. 221) is entirely extinct, and is essentially Palæozoic, ranging from the Silurian to the Trias,

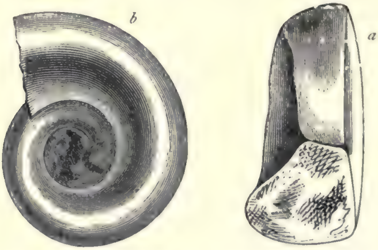


Fig. 221.—*Euomphalus De Cewi* (Billings). *a* Front view; *b* View of the umbilicus. Devonian.

but being most abundant in the Carboniferous Rocks. The shell in this genus is depressed or discoidal, the whorls lying nearly or quite in the same plane. The whorls are angulated or coronated, the aperture is polygonal, the umbilicus is very large, and there is a shelly operculum. The genus *Ophileta* is closely allied to *Euomphalus*, if not identical with it.

FAM. 16. HALIOTIDÆ.—Shell spiral, ear-shaped, or trochoid; aperture large, nacreous. Outer lip notched or perforated. No operculum. Mantle-margin with a posterior fold or siphon, occupying the slit or perforation in the shell.

The living genera *Haliotis* and *Scissurella* are not known in

rocks older than the Miocene Tertiary. The extinct genera *Pleurotomaria* and *Murchisonia* are, on the other hand, of great antiquity, the latter being exclusively Palæozoic, and the former mainly so.

The genus *Haliotis* comprises the so-called "ear-shells," distinguished by their ear-shaped shell, with a minute spire, an enormous aperture, and a series of round perforations in the outer angle of the shell. A few fossil species are known, commencing in the Miocene.

In the genus *Scissurella*, which also commences in the Miocene, the shell is thin, with a large and greatly expanded body-whorl, and the place of the perforations of *Haliotis* is taken by a simple slit in the margin of the outer lip.

The genus *Pleurotomaria* comprises a great number of Palæozoic univalves, which occur in the Silurian, Devonian, and Carboniferous formations. In sediments later than the Carboniferous the genus is largely represented, extending even to the close of the Mesozoic period. In the Jurassic period especially the genus has a great development, most of the forms being more ornate than those from the older rocks. In the Cretaceous Rocks the genus finally dies out, with the sole exception of a single living species. The form of the shell in *Pleurotomaria* (fig. 222) differs considerably in different cases. Very commonly the shell is very similar to that of *Trochus*. In other cases it more nearly resembles *Turbo;* and sometimes it is very much flattened out and depressed. The shell consists of few whorls, of which the last may be disconnected from the others, and is essentially distinguished by its subquadrate aperture, with a deeper or shallower slit in the outer lip. As the shell grows, this slit becomes progressively filled up, forming a well-marked band on the whorls. By this character *Pleurotomaria* may generally be distinguished readily from such shells as *Trochus* and *Turbo.*

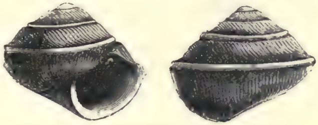


Fig. 222.—*Pleurotomaria Agave.* Lower Silurian (Billings).

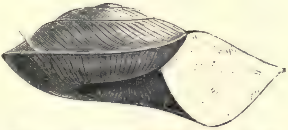


Fig. 223.—*Pleurotomaria Dryope.* Lower Silurian (Billings).

Murchisonia (fig. 224) is another genus of great importance

to the student of the older rocks, as it is exclusively confined to the Palæozoic period, ranging from the Lower Silurian to the Permian. The shell in *Murchisonia* closely resembles that of *Pleurotomaria*, but is usually more elongated and composed of a greater number of whorls. The outer lip is deeply notched, and the whorls have the same band on their exterior as is present in *Pleurotomaria*. The aperture of the shell is slightly channelled in front, and the surface is often variously sculptured and adorned.

We may place here, provisionally, the Palæozoic genus *Holopea* (fig. 225), the exact affinities of which are doubtful. The shell in this genus is spiral, the aperture oval, and the outer lip sinuated near the base. The genus has been compared to the violet-snail (*Ianthina*) of the Atlantic, in which case its place should be here; but its true position is altogether uncertain. It is exclusively Silurian in its range; and it is probable that the genus *Platyceras* should be united with it, in which case the vertical range will be extended at any rate to the Carboniferous.

Fig. 224.—*Murchisonia gracilis* (Hall). Lower Silurian.

Fig. 225.—*Holopea Guelphensis* (Billings). Middle Silurian.

FAM. 17. FISSURELLIDÆ:—Shell conical, patelliform, with a notch in the anterior margin, or a perforation at the apex, which is occupied by the anal siphon. Muscular impression horse-shoe shaped, open in front. The existence of the *Fissurellidæ* in the Palæozoic period is open to considerable doubt; but a good many fossil forms are known from the Secondary and Tertiary Rocks.

The genus *Fissurella* comprises the so-called "Keyhole Limpets," distinguished by having the apex of the shell perforated by a larger or smaller, generally oval aperture. Doubtful examples of the genus have been indicated as occurring in the Devonian and Carboniferous; but there are a good many unequivocal species in the Secondary and Tertiary Rocks. In the Oolitic genus *Rimula* the perforation, instead of being at the apex of the shell, is placed a little above the anterior margin. Lastly, in *Emarginula* the anterior margin is fur-

nished with a longitudinal notch or slit. The species of this genus date from the Trias.

FAM. 18. CALYPTRÆIDÆ:—Shell limpet-shaped, with a more or less spiral apex; interior simple, or divided by a shelly process to which the adductor muscles are attached. Excluding shells whose true position is uncertain, it would appear very questionable if any of the *Calyptræidæ* are found in the Palæozoic Rocks. They are by no means abundant in the Secondary formations; and though more plentiful in the Tertiaries, they attain their maximum in existing seas.

The genus *Calyptræa* includes the so-called "Cup-and-saucer limpets," in which the interior has a half-cup-shaped process attached to the apex of the shell, and open in front. With doubtful exceptions, the fossil species of *Calyptræa* are all of Tertiary age. In the genus *Crepidula* there is a shelly partition covering the posterior half of the interior of the shell. The fossil species date from the Eocene Tertiary. In the genus *Pileopsis* (or *Capulus*) are included the "Bonnet-limpets," in which the apex of the shell is spirally recurved. If *Platyceras* be excluded from this genus, the species of *Pileopsis* date from the Lias; but the former is Palæozoic.

FAM. 19. PATELLIDÆ:—Shell conical, with the apex turned forwards; muscular impression horse-shoe shaped, open in front. Foot as large as the margin of the mantle. Respiratory organ in the form of one or two branchial plumes, lodged in a cervical cavity, or of a series of lamellæ surrounding the animal between the body and the mantle. The *Patellidæ* commence to be represented in the Lower Silurian Rocks, and have continued to the present day.

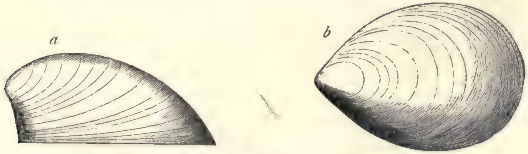


Fig. 226.—*Metoptoma nycteis.* *a* Side view; *b* View of the upper side. Lower Silurian (Billings).

The genera *Patella* (including the common Limpets), *Acmæa*, and *Metoptoma* can hardly be separated in practice from one another. *Patella* and *Acmæa*, at any rate, are palæontologically indivisible, since the only distinctions between them are in the nature of the respiratory organs. In-

cluding these genera, therefore, in one, the range of the Limpets is from the Silurian upwards.

The genus *Metoptoma* (fig. 226) very closely resembles *Patella*, but the muscular scar consists of a number of disconnected cavities. In the typical species, also, the anterior side, under the apex of the shell, is truncated or nearly straight. Species of *Metoptoma* are particularly abundant in the Lower Silurian series; but they range as far as the Carboniferous.

FAM. 20. DENTALIDÆ:—Shell tubular, symmetrical, curved, open at both ends. Aperture circular. Foot pointed, with symmetrical side-lobes. The "Tooth-shells" are generally placed here, in the vicinity of the Limpets; but they are referred by Huxley to the class of the *Pteropoda*. The family comprises the single genus *Dentalium*, well known by the tubular, smooth, or longitudinally striated shell, open at both ends. The fossil species are liable to be confounded with the tubes of Tubicolar Annelides, or a reverse mistake to this may be made. Several species have been described from the Devonian, and more especially from the Carboniferous Rocks, some of them of large size; but more or less doubt obtains as to the true nature of these. The Secondary Rocks have yielded a considerable number of species, and they become still more numerous in the Tertiaries.

FAM. 21. CHITONIDÆ:—Shell multivalve, composed of eight transverse plates, disposed one behind the other in an imbricated manner. Animal with a broad creeping foot; branchiæ forming a series of lamellæ between the foot and the mantle, round the posterior part of the body. The *Chitonidæ* comprise only the single genus *Chiton*, with several more or less distinct sub-genera. The species of the family commence in the Lower Silurian, and are rare as fossils, attaining their maximum at the present day.

Fig. 227.—*Helminthochiton Griffithii*. Silurian. (After Salter.)

The distinctive peculiarities of the shell of the Chitons (fig. 227), by which they may always be separated from the Cirripedes, are the following:—1. The shell never consists of more or fewer than eight pieces. 2. The valves of the shell are always placed one behind the other in a unilinear series. 3. The six middle plates of the shell are divided, each, by lines of sculpturing into three distinct areas—a dorsal and two lateral areas. 4. Each plate is imbedded in the mantle of the animal by forward extensions of its front edge, which are termed the "apophyses."

The Chitons are represented by fossil species in the Silurian,

Devonian, Carboniferous, and Permian Rocks, and are not so excessively rare in the Carboniferous Limestone. They are very poorly represented in the Secondary Rocks, and are by no means abundant in the Tertiaries.

ORDER II. OPISTHOBRANCHIATA :—*Gills placed towards the rear of the body.*

FAM. 22. TORNATELLIDÆ :—Shell external, spiral or convoluted; aperture long and narrow; columella plaited. The *Tornatellidæ* are mainly Mesozoic, ranging from the Trias or from the base of the Jurassic series to the Chalk inclusive, and attaining their maximum in the Cretaceous series. Several genera are entirely extinct, of which the most important is *Cinulia* (fig. 228). In this genus the shell is globular, with a small spire, the outer lip reflected and crenulated interiorly, and the columella with tooth-like folds. All the species are Cretaceous. In the genus *Tornatella*, the shell is ovate, with a well-marked spire, the outer lip thin, and the columella with a strong fold. The fossil species range from the Trias upwards, and the genus, though on the decline, is represented by several living species. Many of the Secondary species belong to more or less distinct sub-genera (*Cylindrites*, *Acteonella*, and *Acteonina*).

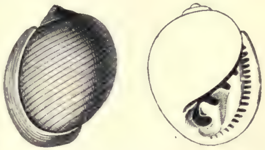


Fig. 228.—*Cinulia Avellana* (*Avellana cassis*, D'Orbigny). Chalk.

FAM. 23. BULLIDÆ :—Shell convoluted, thin; spire small or concealed; lip sharp. Animal often more or less completely investing the shell. The *Bullidæ* commence their existence in the Jurassic period, and have continued to the present day. The only important genus is *Bulla*, comprising the so-called "Bubble-shells" (fig. 229). The species of this genus are not uncommon in the fossil condition, commencing in the Oolites.

Fig. 229.—*Bulla suprajurensis.* Middle Oolites.

FAM. 24. APLYSIADÆ :—Shell absent or rudimentary, concealed by the mantle when present. Animal slug-like; sides extensively lobed and reflected over the back and shell. One or two shells from the younger Tertiary rocks have been referred, with great doubt, to the genus *Aplysia.*

FAM. 25. PLEUROBRANCHIDÆ :—Shell limpet-like or concealed, rarely wanting. Mantle or shell covering the back of

the animal. Two doubtful species belonging to the genus *Umbrella* have been described from the Tertiaries; but the family is otherwise unknown in the fossil condition.

CHAPTER XXII.

GASTEROPODA—Continued.

Heteropoda and Pulmonifera.

Order III. Heteropoda or Nucleobranchiata:—The Gasteropods of this order differ from the typical members of the class in being *organised to lead an existence in the open ocean, locomotion being effected by a fin-like tail, or by a fan-shaped vertically-flattened ventral fin.* They are found swimming at or near the surface of the ocean; and the body may be completely protected by a shell, within which the animal can retire, and which can be closed by an operculum. In other cases, as in *Carinaria* (fig. 230), the body is large, and there is

Fig. 230.—Heteropoda. *Carinaria cymbium.* *p* Proboscis; *t* Tentacles; *b* Branchiæ; *s* Shell; *f* Foot; *d* Disc. (After Woodward.)

only a small shell protecting the gills and heart. In other cases, again, the shell is completely wanting. The order is divided into the two families of the *Firolidæ* and *Atlantidæ*. The former of these is represented by a single species only, from the Miocene Tertiary. The latter had a great development in Palæozoic seas, and is represented in the formations of this period by several remarkable genera.

Fam. 1. Firolidæ:—Body large, never completely protected by a shell, often shell-less. Sometimes a small delicate

hyaline shell, placed on the back, protecting the gills. The only genus of this family which is represented in a fossil state is *Carinaria* (fig. 230), a single species of which has been found in deposits of Tertiary age (Miocene).

FAM. 2. ATLANTIDÆ:—Animal furnished with a well-developed shell, into which it can retire. Shell symmetrical, discoidal, destitute of septa, often provided with an operculum. This family is represented by the genera *Bellerophon*, *Maclurea*, *Cyrtolites*, *Ecculiomphalus*, and *Porcellia*, most of which are exclusively Palæozoic, whilst the others are mainly so.

In the genus *Bellerophon* (fig. 231) the shell is symmetrical, convoluted, the coils of the shell usually lying in one plane.

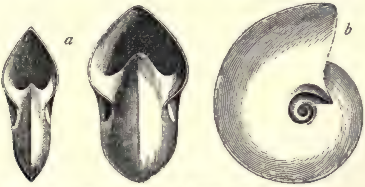


Fig. 231.—*Bellerophon Argo* (Billings). *a* Front view; *b* side view. Lower Silurian.

The whorls are few, smooth or sculptured, and there is a dorsal keel along the convex margin of the shell. The aperture is often more or less expanded, and is in most instances emarginate or deeply notched on the dorsal side. The genus ranges from the Lower Silurian to the Carboniferous. The *Bellerophina* of the Gault (Upper Cretaceous) is doubtfully allied to *Bellerophon*, and may belong to the *Pteropoda*.

The genus *Maclurea* is very remarkable in its structure, and all the known species are entirely confined to the Lower Silurian Rocks. The shell (fig. 232) in this singular genus is "discoidal, few-whorled, longitudinally grooved at the back, and slightly rugose with lines of growth; dextral side convex, deeply and narrowly perforated; left side flat, exposing the inner whorls; operculum sinistrally sub-spiral, solid, with two internal projections, one of them beneath the nucleus, very thick and rugose" (Woodward). *Maclurea* has been variously regarded as "dextral" or "sinistral;" but the probabilities are in favour of the view that it is truly *dextral*. In this case, the flat side of the shell is the umbilicus, and the spire must be regarded as sunk below the general surface of the shell. (On this view the specimen figured at *b*, fig. 232, is represented upside down.) The species of *Maclurea* occur chiefly at the base

of the Lower Silurian series both in North America and in Scotland, occurring in some localities in the greatest profusion.

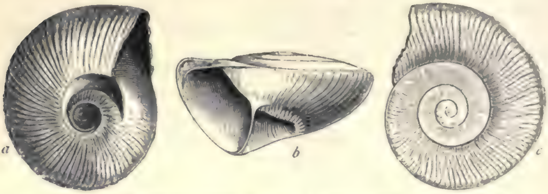


Fig. 232.—*Maclurea crenulata.* *a* Spire ; *b* front , *c* base. Lower Silurian.

The genus *Ophileta* (fig. 233) of the Silurian Rocks may be mentioned here, though its true affinities are extremely doubt-

Fig. 233.—*Ophileta bella* (Billings). Different views of a nearly perfect specimen. Quebec Group (Upper Cambrian ?)

ful. The shell in this genus is discoidal, and very closely resembles that of *Euomphalus*. The aperture, however, is stated by Mr Billings to have a sinus in the lower lip and a notch in the upper lip—characters which are not present in *Maclurea*. It is a matter of question whether *Ophileta* should be regarded as comprising species of *Maclurea* with slender whorls, or whether it should be placed in the *Turbinidæ*, in or near *Euomphalus*, or whether it should not be placed in the *Haliotidæ* and be regarded as a discoidal *Pleurotomaria*.

Fig. 234.—*Cyrtolites ornatus.* Lower Silurian.

In the genus *Cyrtolites* (fig. 234) the shell is thin, symmetrical, discoidal, or coiled into the shape of a horn, the whorls more or less disconnected, furnished with a keel, and sculptured. The species of this

genus range from the Lower Silurian to the Carboniferous Rocks, and are, therefore, exclusively Palæozoic.

In *Ecculiomphalus* (fig. 235) the shell is very like that of *Cyrtolites*, but the whorls are few in number, and are widely separated from one another. The shell is thin, and the coils

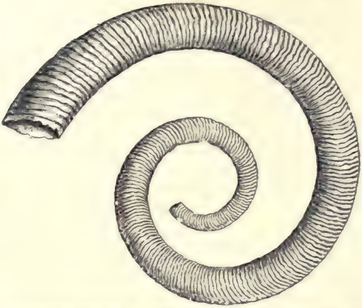


Fig. 235.—*Ecculiomphalus distans.* Quebec Group (Upper Cambrian?)

lie in the same plane. The species of this genus range from the Lower Silurian to the Carboniferous, and have been compared to *Euomphali* imperfectly rolled up; but the true affinities of the genus are doubtful.

Lastly, the genus *Porcellia* includes shells which are composed of many whorls coiled into a flat spiral. The whorls are keeled, and the aperture has a dorsal slit. The species of this genus are mainly Palæozoic, but range into the Trias.

SECTION B. PULMONIFERA:—Respiration aerial, by means of a pulmonary chamber. The *Pulmonifera* include the ordinary Land-snails, Slugs, Pond-snails, &c., and are usually provided with a well-developed shell; though this may be rudimentary (as in the Slugs), or even wanting. In the Land-snails and Pond-snails there is a well-developed shell into which the animal can retire completely. The Slugs, again, have a merely rudimentary shell which is completely concealed within the mantle. The completely shell-less forms are necessarily wholly unknown as fossils. The Slugs, with a rudimentary shell, are only doubtfully represented in a fossil state, and that only in the Tertiary Rocks. The abundance of the shell-bearing forms as fossils depends mainly on the habits of the animal. The Land-snails, being terrestrial in their habits, are, necessarily, but sparingly represented as fossils, and they do not date back

to a time anterior to the Carboniferous. The Pond-snails, being exclusively confined to fresh water, are only known as fossils in fluviatile and lacustrine deposits, and they are exclusively Secondary and Tertiary, not being known in the Palæozoic period. The *Pulmonifera* are divided into the two orders of the *Inoperculata* and *Operculata*, according as the shell is destitute of an operculum, or is provided with this apparatus.

ORDER IV. INOPERCULATA:—*Shell not provided with an operculum.*

FAM. 1. HELICIDÆ:—Shell well developed, capable of containing the entire animal. With the exception of *Pupa* and *Zonites* (the last a sub-genus of *Helix*), all the *Helicidæ* belong to the Tertiary and Recent periods. As they are all terrestrial in their habits, they are necessarily of rare occurrence as fossils, occurring chiefly in fluviatile and lacustrine deposits. The two genera above mentioned have been found in the Coal-Measures, and are the oldest forms of the group. The chief fossil genera are *Helix*, *Bulimus*, *Achatina*, *Pupa*, and *Clausilia*.

In the genus *Helix* are the ordinary Land-snails (fig. 236), in which the shell is conical, sometimes depressed, or sometimes discoidal; the aperture transverse, crescentic or rounded, and the columella perforated or imperforate. The Land-snails, with one exception, are all confined to the Tertiary and Recent periods. The exception to this statement is the *Zonites priscus* (fig. 236), discovered by Dr Dawson in the Coal-Measures of

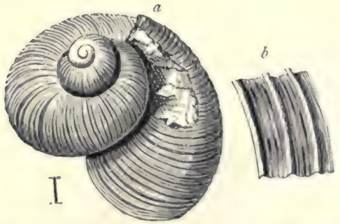


Fig. 236.—*Zonites* (*Conulus*) *priscus* (after Dawson). *a* Specimen enlarged twelve diameters; *b* Sculpture, magnified. Coal-Measures, Nova Scotia.

Nova Scotia. This is a true Land-snail referred to *Zonites* or *Conulus*, a sub-genus of *Helix* itself.

In *Bulimus* the shell is turreted or oblong, the columella generally simple, and the outer lip usually expanded and thickened. In the nearly allied genus *Achatina* the columella

is twisted, and the lips of the shell-aperture are thin. Both genera date their existence from the Eocene Tertiary.

In the genus *Pupa* the shell is cylindrical or oblong, with a round, often toothed, aperture. The oldest member of this genus is the *Pupa vetusta* (fig. 237), discovered by Dr Dawson in the Coal-Measures of Nova Scotia, in the hollow trunk of an erect *Sigillaria*. This ancient form is remarkably like some living "Chrysalis-shells," and there appears to be no reason for framing a new genus (*Dendropupa*) for its reception. With the exception of this little shell, all the fossil species of *Pupa* are confined to the Tertiary period, commencing in the Eocene.

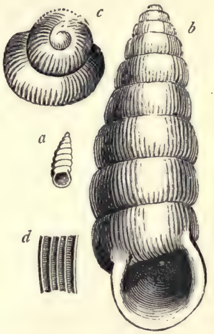


Fig. 237.—*Pupa (Dendropupa) vetusta.* (After Dawson.) *a* Natural size; *b* Enlarged; *c* Apex enlarged; *d* Sculpture, magnified. Coal-Measures.

In the genus *Clausilia* the shell is spindle-shaped, coiled into a left-handed spiral ("sinistral"), with an elliptical aperture, partially contracted by shelly processes. The *Clausiliæ*, so far as known, date their existence from the Eocene Tertiary.

Fam. 2. Limacidæ:—Shell rudimentary, usually internal or concealed by the mantle. The "Slugs" are included in this family, and they are only known in the fossil state by doubtful remains in the Miocene and Pliocene Tertiary. A species of *Testacella* has also been indicated as occurring in the Miocene.

Fam. 3. Limnæidæ:—Shell well developed, thin and horn-coloured. Aperture simple; lip sharp. The *Limnæidæ* are all inhabitants of fresh water, and they are found in fluviatile and lacustrine deposits. They are believed to commence in the Jurassic period, members of this family having been described from the Lias and from the Purbeck beds (Upper Oolites). It is not, however, until we reach the base of the Cretaceous system (Weald Clay) that these forms appear in any abundance.

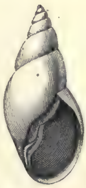


Fig. 238.—*Limnæa pyramidalis.* Eocene.

The genus *Limnæa* (fig. 238) includes the so-called "Pond-snails," characterised by their thin, spiral,

elongated shells, with a large body-whorl and an obliquely-twisted columella. The species of this genus commence in the Wealden (Lower Cretaceous) — perhaps in the Upper Oolites—and are abundantly represented throughout the Tertiary series.

In the genus *Physa* (fig. 239) the shell is left-handed ("sinistral"), ovate, thin, and polished, with the aperture rounded in front. Species of this genus have been indicated as occurring in the Purbeck beds (Upper Oolites) and Wealden (Cretaceous). Most of the fossil species, however, belong to the Tertiary period, and the genus attains its maximum at the present day.

Fig. 239.—*Physa columnaris.* Eocene.

The genus *Ancylus* comprises the so-called "River-Limpets," at once distinguished by their thin, conical, limpet-shaped shells. A few fossil species are known, chiefly, if not exclusively, confined to the Tertiary period.

The genus *Planorbis* comprises a number of well-known fresh-water shells, in which the shell is discoidal and many-whorled, the aperture crescentic, and the lip thin. The fossil species of this genus date from the Lias (?), but are not plentiful except in the Tertiary deposits, whence a large number of forms has been obtained.

FAM. 4. AURICULIDÆ:—Shell spiral, with a horny epidermis; aperture elongated and denticulated. The species of this family inhabit salt marshes and places overflowed by the sea. They are of little importance as fossils, dating from the Eocene Tertiary.

ORDER V. OPERCULATA:—*Shell furnished with an operculum.*

FAM. 5. CYCLOSTOMIDÆ:—Shell spiral, rarely elongated, often depressed. Aperture nearly circular. Operculum spiral. The genus *Cyclostoma* (fig. 240) includes almost all the fossil species of this family, and dates from the Eocene Tertiary. All the members of this family are terrestrial in their habits, and they are of small importance as fossils.

Fig. 240.—*Cyclostoma Arnoudii.* Eocene Tertiary.

FAM. 6. ACICULIDÆ:—Shell elongated, cylindrical; operculum thin and subspiral. A species of *Acicula* has been indicated as occurring in the Pliocene Tertiary; but the family is otherwise unrepresented by fossil forms.

CHAPTER XXIII.

CLASS PTEROPODA.

THE *Pteropoda* are defined by being *free and pelagic*, swimming by means of two wing-like appendages (epipodia), developed from each side of the anterior extremity of the body. The flexure of the intestine is neural.

As to the position of the *Pteropoda* in the Molluscan scale, they must be looked upon as inferior in organisation to any of the *Gasteropoda*, of which class they are often regarded as the lowest division. They permanently represent, in fact, the transient, larval stage of the Sea-snails.

The living Pteropods are all of small size, and are found swimming at the surface of the open ocean, often in enormous numbers. Locomotion is effected by two wing-like fins (fig. 241) developed from the sides of the head. In some cases the body is naked and unprotected; but there is commonly a symmetrical glassy shell, either consisting of a dorsal and ventral plate united, or forming a spiral.

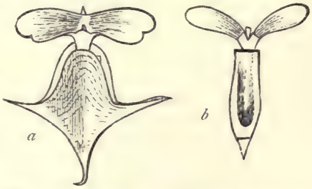


Fig. 241.—Pteropoda. *a Cleodora pyramidata; b Cuvieria columnella.* (After Woodward.)

The *Pteropoda* are divided into two orders, termed *Thecosomata* and *Gymnosomata;* the former characterised by possessing an external shell and an indistinct head; the latter by being devoid of a shell, and by having a distinct head, with fins attached to the neck.

The Gymnosomatous Pteropods, in which there is no shell, as a matter of course, are wholly unknown in the fossil condition. The Thecosomatous Pteropods, in which there is a shell, are divided into two families—the *Hyaleidæ* and *Limacinidæ.* The latter comprises forms in which there is a small spiral shell, which is sometimes provided with an operculum; but it is unrepresented in a fossil state. The former family comprises forms in which the shell is symmetrical, straight or curved, globular or needle-shaped, and it is represented by a considerable number of fossil forms, most of which are extremely unlike any known living examples of the class, being often of comparatively colossal dimensions. The fossil forms

mostly belong to the genera *Hyalea*, *Cuvieria*, *Cleodora*, *Theca*, *Pterotheca*, *Tentaculites*, and *Conularia;* but other less important types are known to have existed in past time. Of the above-mentioned generic forms, the first three are well represented at the present day by living forms. The remaining four are almost exclusively Palæozoic, *Conularia* alone surviving into the earlier portion of the Mesozoic period. Not only is this the case, but the forms in question all commence their existence in the Lower Silurian or Upper Cambrian, and none of them except *Conularia* transgresses the upper limit of the Devonian Rocks. Lastly, almost all these forms are of comparatively gigantic size, and they differ in many respects from living forms.

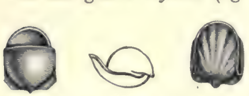


Fig. 242.—*Hyalea Orbignyana*. Miocene Tertiary.

In the genus *Hyalea* (fig. 242) the shell is globular, translucent, the dorsal plate extended into a hood; the aperture is contracted, with a lateral slit on each side. The fossil species are only known in the Miocene and Pliocene Tertiary, and the genus attains its maximum in existing seas. *Cleodora* has a pyramidal shell, and dates from the Miocene; and *Cuvieria* (fig. 241) has a cylindrical shell, and dates from the Pliocene. Both these genera attain their maximum at the present day.

Fig. 243.—*Theca operculata* and its operculum. (After Salter.) From the Tremadoc Slates (Upper Cambrian ?)

The genus *Theca* (the *Hyolithes* of Continental and American palæontologists) comprises a number of singular forms in which the shell is straight, sheath-shaped, tapering to a point, triangular, and destitute of lateral appendages (fig. 243). The mouth of the shell is trigonal, sometimes closed by an operculum, sometimes furnished with curved lateral appendages. The length of the shell is commonly about an inch or an inch and a half. Nearly ninety species of this genus are enumerated by M. Barrande, distributed in the Upper Cambrian, Silurian, and Devonian formations, but not extending into the Carboniferous period.

The genus *Pterotheca* of Salter is exclusively Silurian, and is characterised by having the "shell transversely oval, bilobed, with wavy sides and a strong median keel; ventral plate short, narrow, and flat."

The genus *Conularia* is one of the most extraordinary of the extinct genera of the Pteropods, if only for the enormous size attained by many examples. The shape of the shell is very like that of some living Pteropods, but specimens occasionally reach the length of nearly a foot, with a breadth of more than an inch. The shell in *Conularia* (fig. 244) is straight, tapering towards one end, and having a sub-quadrate or rhomboidal aperture at the other. The form of the shell is generally distinctly four-sided, the sides being finely striated with transverse lines. The shell is generally of extreme tenuity; but the internal cavity is sometimes restricted by concentric lamellæ, and the apex may be partitioned off. M. Barrande enumerates eighty-three species of *Conularia*, most of which are Palæozoic, commencing in the lowest Silurian deposits. The genus, however, extends into the Mesozoic Rocks, the last species, so far as at present known, appearing in the Lias.

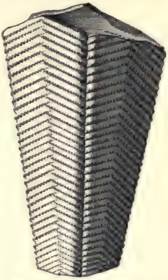


Fig. 244.—*Conularia ornata.* Devonian.

Lastly, the genus *Tentaculites* comprises a number of singular Palæozoic fossils, the true position of which cannot be said to be absolutely free from doubt. Most authorities now place *Tentaculites*, with apparently good reason, in the *Pteropoda;* but others would still refer this genus to the Tubicolar Annelides. It must be admitted, also, that in some respects *Tentaculites* approximates pretty closely to the Annelidous genera *Conchicolites* and *Cornulites.* Upon the whole, however, the mode of occurrence of *Tentaculites* and its undoubted free habit of existence leave little doubt as to its true place being amongst the Pteropods. The shell of *Tentaculites* (fig. 245) has the form of a straight conical tube, tapering towards one extremity to a pointed closed apex, and expanding towards the other to a circular aperture. The walls of the shell are thin, and are surrounded with numerous thickened rings or annulations, sometimes with intermediate striæ, over a whole or part of the length of the tube. The size of *Tentaculites* varies much in different cases, being sometimes less than a couple of lines in length, and sometimes

Fig. 245. — *Tentaculites ornatus.* Upper Silurian. Europe and North America.

attaining a length of an inch or more. Fifty-two species of *Tentaculites* are enumerated by M. Barrande, commencing in the Lower Silurian and ranging into the Devonian. The genus is essentially Silurian, and examples of some species often occur in myriads through a considerable thickness of strata.

CHAPTER XXIV.

CLASS CEPHALOPODA.

CLASS IV. CEPHALOPODA.—The members of the *Cephalopoda* are defined by the possession of *eight or more arms placed in a circle round the mouth; the body is enclosed in a muscular mantle-sac, and there are two or four plume-like gills within the mantle. There is an anterior tubular orifice (the "infundibulum" or "funnel"), through which the effete water of respiration is expelled.*

The *Cephalopoda*, comprising the Cuttle-fishes, Squids, Pearly Nautilus, &c., constitute the most highly organised of the classes of the *Mollusca*. They are all marine and carnivorous, and are possessed of considerable locomotive powers. At the bottom of the sea they can walk about, head downwards, by means of the arms which surround the mouth, and which are usually provided with numerous suckers or "acetabula." They are also enabled to swim, partly by means of lateral expansions of the integument or fins (not always present), and partly by means of the forcible expulsion of water through the tubular "funnel," the reaction of which causes the animal to move in the opposite direction.

The majority of the living Cephalopods are naked, possessing only an internal skeleton, and this often a rudimentary one; but the Argonaut (Paper Nautilus) and the Pearly Nautilus are protected with an external shell, though the nature of this is extremely different in the two forms.

The body in the *Cephalopoda* is symmetrical, and is enclosed in an integument which may be regarded as a modification of the mantle of the other *Mollusca*. Ordinarily there is a tolerably distinct separation of the body into an anterior cephalic portion (*prosoma*), and a posterior portion, enveloped in the mantle, and containing the viscera (*metasoma*). The head is very distinct, bearing a pair of large globular eyes, and having the mouth in its centre. The mouth is surrounded by a circle

of eight, ten, or more, long muscular processes, or "arms" (fig. 246), which are generally provided with rows of suckers. In the Octopod Cuttle-fishes there are only eight arms, and these are all nearly alike. In the Decapod Cuttle-fishes there are ten arms, but two of these—called "tentacles"—are much longer than the others, and bear suckers only at their extremities, which are enlarged and club-shaped. In the Pearly Nautilus the arms are numerous, and are devoid of suckers.

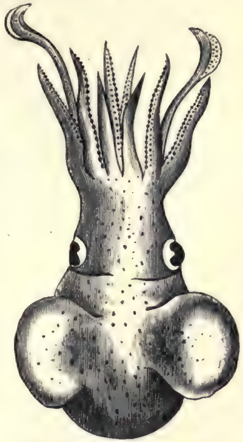


Fig. 246.—Cephalopoda. *Sepiola Atlantica*, one of the Cuttle-fishes (after Woodward).

The parts of the *Cephalopoda* which may be preserved in a fossil condition, and which thus interest the palæontologist, are the *mandibles*, the *ink-bag*, and the *skeleton*, whether this be internal or external.

The *mandibles* are contained within the mouth or "buccal cavity" of the animal, and have the form of powerful jaws, working vertically like the beak of a bird. They are horny or calcareous, and in shape closely resemble the beak of a parrot, with this difference, that the largest of the two mandibles is placed inferiorly. Mandibles of this nature are present in both the Cuttle-fishes and the Pearly Nautilus, and they doubtless existed in all the extinct forms. They not uncommonly occur as fossils, but they do not appear to have been observed out of the Jurassic and Cretaceous Rocks. They are commonly called "Rhyncholites," and genera such as *Rhynchoteuthis* have been founded upon them (fig. 247).

The *ink-bag* is a special gland possessed by the Cuttle-fishes, for the purpose of secreting an inky fluid, which the animal can discharge into the water, so as to enable it to escape when menaced or pursued. The secretion of the ink-bag consists of finely-divided particles of carbon suspended in fluid, and it is extremely indestructible. The ink-bag, with its contained secretion, is not uncommonly found in the fossil condition; but it has only been observed in strata of Secondary age. In the Tetrabranchiate Cephalopods, in which there is an external

shell, and this means of defence is not needed, there is no ink-bag.

The *shell* of the *Cephalopoda* is sometimes external, sometimes internal. The internal skeleton is known as the "cuttle-

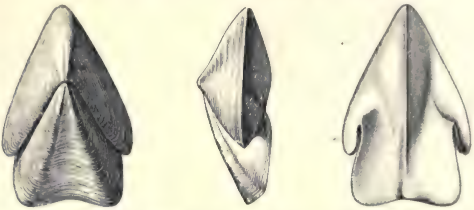


Fig. 247.—*Rhynchoteuthis Astieriana*. Lower Greensand (Cretaceous).

bone," "sepiostaire," or "pen" (*gladius*), and may be either corneous or calcareous. In some cases it is rendered complex by the addition of a chambered portion or "phragmacone," which is to be regarded as a visceral skeleton or "splanchno-skeleton." In *Spirula* the phragmacone is the sole internal skeleton, and is coiled into a spiral, the coils of which lie in one plane, and are near one another, but not in contact. It thus resembles the shell of the Pearly Nautilus, but it is *internal*, and differs, therefore, entirely from the *external* shell of the latter. The only living Cephalopods which are provided with an external shell are the Paper Nautilus (*Argonauta*), and the Pearly Nautilus (*Nautilus pompilius*); but not only is the structure of the animal different in each of these, but the nature of the shell itself is entirely different. The shell of the Argonaut is involuted, but is not divided into chambers, and it is secreted by the webbed extremities of two of the dorsal arms of the female. The arms are bent backwards, so as to allow the animal to live in the shell, but there is in reality no organic connection between the shell and the body of the animal. In fact, the shell of the Argonaut, being confined to the female, and serving by its empty apex as a receptacle for the ova, may be looked upon as a "nidamental shell," or, as it is secreted by a modified portion of the foot, it may more properly be regarded as a "pedal shell." The shell of the Pearly Nautilus (fig. 248), on the other hand, is a true pallial shell, and is secreted by the body of the animal, to which it is organically connected. It is involuted, but it differs from the shell of the Argonaut in being divided into a series of chambers by shelly

partitions or septa, which are pierced by a tube or "siphuncle," the animal itself living in the last chamber only of the shell.

The *Cephalopoda* are divided into two extremely distinct and well-marked orders, termed the *Dibranchiata* and *Tetrabranchiata.* The former is characterised by the possession of two gills only, and by the fact that the shell, if external (as it very rarely is), is never chambered. In this order are comprised the living Cuttle-fishes, Squids, and Paper Nautilus, with the extinct family of the *Belemnitidæ.* The latter is distinguished by the presence of four gills, and by the possession of an external many-chambered shell. This order is abundantly represented in past time, but has no other living representative than the Pearly Nautilus alone. The following table gives the characters and leading genera of the families of *Cephalopoda* :—

Synopsis of the Families of the Cephalopoda.

Class Cephalopoda.

Order I. Dibranchiata.

Animal with two branchiæ ; not more than eight or ten arms, provided with suckers ; an ink-bag Shell commonly internal and rudimentary ; rarely external, but not chambered.

Section A. Octopoda.

Arms eight, suckers sessile.

Fam. 1. *Argonautidæ.*

Female provided with a calcareous, external, monothalamous shell, secreted by the webbed extremities of two of the dorsal arms. Gen. *Argonauta.*

Fam. 2. *Octopodidæ.*

Shell internal, rudimentary, uncalcified. No pallial fins in most. Ill. Gen. *Octopus*, *Tremoctopus*, *Eledone*, *Pinnoctopus.*

Section B. Decapoda.

Arms eight, with two clavate " tentacles ;" suckers pedunculated.

Fam. 3. *Teuthidæ.*

Shell an internal horny "pen" or "gladius." Fins mostly terminal. Ill. Gen. *Loligo*, *Onychoteuthis*, *Ommastrephes.*

Fam. 4. *Belemnitidæ.*

Shell internal, composed of a conical chambered portion ("phragmacone") with a marginal siphuncle, produced into a horny plate or "pen," and lodged in a cylindrical fibrous "guard." Ill. Gen. *Belemnites*, *Belemnitella*, *Belemnoteuthis.*

Fam. 5. *Sepiadæ.*

Shell calcareous, consisting of a broad, laminar plate, terminating in an imperfectly-chambered apex ("phragmacone"). Ill. Gen. *Sepia*, *Beloptera*, *Spirulirostra.*

Fam. 6. *Spirulidæ.*

Shell internal, nacreous, chambered, discoidal ; the whorls separate ; a ventral siphuncle. Gen. *Spirula.*

Order II. Tetrabranchiata.

Animal with four gills ; arms more than ten, without suckers ; no ink-bag ; shell external, chambered, and siphuncled.

Fam. 1. *Nautilidæ.*

Sutures of the shell simple ; the siphuncle central, sub-central, or near the concavity of the curved shells, simple.

Sub-family Nautilidæ proper.

Body-chamber capacious ; aperture simple ; siphuncle central or internal. Ill. Gen. *Nautilus, Lituites, Trochoceras.*

Sub-family Orthoceratidæ.

Shell straight, curved, or discoidal ; body-chamber small ; aperture contracted ; siphuncle complicated. Ill. Gen. *Orthoceras, Phragmoceras, Cyrtoceras.*

Fam. 2. *Ammonitidæ.*

Shell discoidal, curved, spiral, or straight ; body-chamber elongated ; aperture guarded by processes, or closed by an operculum ; sutures angulated, lobed, or foliaceous ; siphuncle external or dorsal (on the convex side of the curved shells). Ill. Gen. *Ammonites, Ceratites, Baculites, Turrilites, Scaphites, Ancyloceras.*

As regards their general distribution in time, the Cephalopods are largely represented in all the primary groups of stratified rocks from the Lower Silurian up to the present day. Of the two orders of *Cephalopoda*, the *Tetrabranchiata* is the oldest, attaining its maximum in the Palæozoic period, decreasing in the Mesozoic and Kainozoic epochs, and being represented at the present day by the single form, *Nautilus pompilius*. Of the sections of this order, the *Nautilidæ* proper and the *Orthoceratidæ* are pre-eminently Palæozoic, and the *Ammonitidæ* are not only pre-eminently but are almost exclusively Secondary. Of the abundance of the two former families in the Silurian seas some idea may be obtained when it is mentioned that over a thousand species have been described by M. Barrande from the Silurian basin of Bohemia alone. The *Nautilidæ* proper have gradually decreased in numbers from the Palæozoic, through the Secondary and Tertiary periods, to the present day. The *Orthoceratidæ* died out much sooner, being exclusively Palæozoic, with the exception of the genera *Orthoceras* itself and *Cyrtoceras*, which survived into the commencement of the Secondary period, finally dying out in the Trias.

The second family of the *Tetrabranchiata*—viz., the *Ammonitidæ*—is almost exclusively Secondary, being very largely represented by numerous species of the genera *Ammonites, Ceratites, Baculites, Turrilites*, &c. The only Palæozoic genera are *Goniatites* and *Bactrites*, of which the former is found from the Upper Silurian to the Trias, whilst the latter is a Silurian and Devonian form. The genus *Ceratites* is characteristically Triassic, but it is said to occur in the Devonian Rocks, and some species are Cretaceous. All the remaining genera are exclusively Secondary, the genera *Baculites, Turrilites, Hamites* and *Ptychoceras* being confined to the Cretaceous period.

Of the Dibranchiate Cephalopods the record is less perfect, as they have few structures which are capable of preservation. They attain their maximum, as fossils, shortly after their first appearance in the Secondary Rocks, where they are represented by the large and important family of the *Belemnitidæ*. Some of the *Teuthidæ* and *Sepiadæ* are found both in the Secondary and in the Tertiary Rocks, and two species of Argonaut have been discovered in the later Tertiaries. No example of a Dibranchiate Cephalopod is known from the Palæozoic deposits, and the order attains its maximum at the present day.

CHAPTER XXV.

TETRABRANCHIATE CEPHALOPODS.

THE Tetrabranchiate Cephalopods are characterised by being *creeping animals, protected by an external, many-chambered shell, the septa between the chambers of which are perforated by a membranous or calcareous tube, termed the "siphuncle." The arms are numerous, and are devoid of suckers; the branchiæ are four in number, two on each side of the body; the funnel does not form a complete tube; and there is no ink-bag.*

The Tetrabranchiate Cephalopods have an enormous development in past time, several thousand species, mostly belonging to extinct types, being known from the Palæozoic Rocks alone. In the Mesozoic Rocks the members of this order were almost equally abundant. In the Tertiary Rocks the order is reduced to the single genus *Nautilus*, represented at the present day by the single species *Nautilus pompilius* (the Pearly Nautilus). The palæontological importance of this order being so great, it may be as well to preface the account of the extinct forms by a short description of the structure of the living *Nautilus pompilius*, as described by Professor Owen, from the only perfect specimen which has as yet been obtained.

The soft structures in the Pearly Nautilus may be divided into a posterior, soft, membranous mass (*metasoma*), containing the viscera, and an anterior muscular division, comprising the head (*prosoma*); the whole being contained in the outermost, capacious chamber (the body-chamber) of the shell, from which the head can be protruded at will. The shell itself (fig. 248) is involuted and many-chambered, the animal being contained successively in each chamber, and retiring from it as its size

becomes sufficiently great to necessitate the acquisition of more room. Each chamber, as the animal retires from it, is walled off by a curved, nacreous septum; the communication between the chambers being still kept up by a membranous tube or siphuncle, which opens at one extremity into the pericardium,

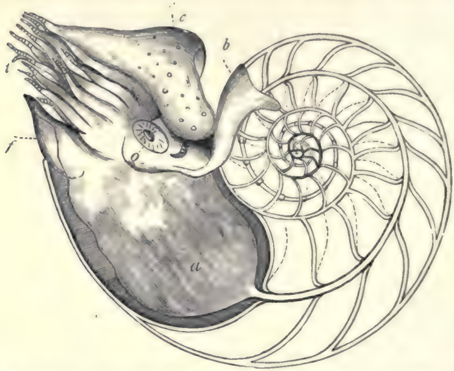


Fig. 248.—Pearly Nautilus (*Nautilus pompilius*). *a* Mantle; *b* Its dorsal fold; *c* Hood; *o* Eye; *t* Tentacles; *f* Funnel.

and is continued through the entire length of the shell. The position of the siphuncle is in the centre of each septum.

Posteriorly the mantle of the Nautilus is very thin, but it is much thicker in front, and forms a thick fold or collar surrounding the head and its appendages. From the sides of the head spring a great number of muscular prehensile processes or "arms," which are annulated, but are not provided with cups or suckers. In the centre of the head is the mouth, surrounded by a circular fleshy lip, external to which is a series of labial processes. The mouth opens into a buccal cavity, armed with two horny mandibles, partially calcified towards their extremities, and shaped like the beak of a parrot, except that the under mandible is the longest. There is also a "tongue," which is fleshy and sentient in front, but is armed with recurved teeth behind. The gullet opens into a large crop, which in turn conducts to a gizzard, and the intestine terminates at the base of the funnel. On each side of the crop is a well-developed liver.

The heart is contained in a large cavity, divided into several

chambers, and termed the "pericardium" (Owen). The respiratory organs are in the form of four pyramidal branchiæ, two on each side.

The chief masses of the nervous system are the cerebral and infra-œsophageal ganglia, which are partially protected by a cartilaginous plate, which is to be regarded as a rudimentary cranium, and which sends out processes for the attachment of muscles. The organs of sense are two large eyes, attached by short stalks to the sides of the head, and two hollow plicated sub-ocular processes, believed to be olfactory in their function.

The reproductive organs of the female consist of an ovary, oviduct, and accessory nidamental gland.

There is no ink-bag, and the funnel does not form a complete tube, but consists of two muscular lobes, which are simply in apposition. It is the organ by which swimming is effected, the animal being propelled through the water by means of the reaction produced by the successive jets emitted from the funnel. The function of the chambers of the shell appears to be that of reducing the specific gravity of the animal to near that of the surrounding water, since they are probably filled with some gas secreted by the animal, or with water itself. The function of the siphuncle is unknown, except in so far as it doubtless serves to maintain the vitality of the shell.

Shell of the Tetrabranchiata.—The shells of all the *Tetrabranchiata* agree in the following points :—

1. The shell is external.

2. The shell is divided into a series of chambers by plates or "septa," the edges of which, where they appear on the shell, are termed the "sutures."

3. The outermost chamber of the shell is the largest, and is the one inhabited by the animal.

4. The various chambers of the shell are united by a tube, termed the "siphuncle."

Agreeing in all these fundamental points of structure, two very distinct types of shell may be distinguished as characteristic of the two families *Nautilidæ* and *Ammonitidæ*, into which the order *Tetrabranchiata* is divided.

In the family *Nautilidæ* (fig. 249), the "septa" of the shell are simple, curved, or slightly lobed; the "sutures" are more or less completely plain; and the "siphuncle" is central, subcentral, or internal (*i.e.*, on the *concave* side of the curved shells).

In the family *Ammonitidæ* (fig. 249), on the other hand, the septa are folded and complex; the sutures are angulated, zigzag, lobed, or foliaceous; and the siphuncle is external (*i.e.*, on the *convex* side of the curved shells).

In both these great *types* of shell, a series of representative *forms* exists, resembling each other in the manner in which the shell is folded or coiled, but differing in their fundamental structure. All these different forms may be looked upon as produced by the modification of a greatly-elongated cone, the structure of which may be in conformity with the type either of the *Nautilidæ* or of the *Ammonitidæ.* The following table (after Woodward) exhibits some of the representative forms in the two families :—

	Nautilidæ.	*Ammonitidæ.*
Shell straight	Orthoceras . .	Baculites.
,, bent on itself . .	Ascoceras . .	Ptychoceras.
,, curved	Cyrtoceras . .	Toxoceras.
,, spiral	Trochoceras .	Turrilites.
,, discoidal	Gyroceras . .	Crioceras.
,, discoidal and produced	Lituites . . .	Ancyloceras.
,, involute	Nautilus . . .	Ammonites.

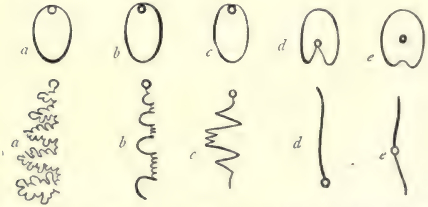


Fig. 249.—Diagram to illustrate the position of the siphuncle and the form of the septa in various Tetrabranchiate Cephalopoda. The upper row of figures represents transverse sections of the shells, the lower row represents the edges of the septa. *a a Ammonite* or *Baculite ; b b Ceratite ; c c Goniatite ; d d Clymenia ; e e Nautilus* or *Orthoceras.*

DISTRIBUTION OF TETRABRANCHIATA IN TIME.—Regarded as a whole, the Tetrabranchiate Cephalopods form a group which early attained its maximum, and which is now almost extinct. The greatest development, in point of numbers, took place in the Palæozoic period ; and the forms then existing belonged to decidedly simpler types than those which followed them. The greatest number of *types* existed during the Mesozoic period ; and here the order still maintained a great abundance of individuals. With the close of the Secondary epoch a large number of complex types disappeared wholly, and the order was left without any representative in the Tertiary Rocks except the simple and ancient genus *Nautilus.*

As regards the two great sections of the order, the *Nautilidæ* are the most ancient, dating their existence from the Lower Silurian, if not from the Upper Cambrian. Not only is this the case, but they are pre-eminently Palæozoic, very few forms surviving into the Secondary period, and only one into the Tertiary. The *Ammonitidæ*, on the other hand, are pre-eminently Mesozoic, and no member of this group is known to have survived into the Kainozoic period. This group, however, is represented by two comparatively simple types in the Palæozoic period, commencing their existence from the Silurian.

In the following are given the characters and distribution in time of the leading forms of the Tetrabranchiate Cephalopods :—

NAUTILIDÆ.

FAM. I. NAUTILIDÆ.—*Sutures of the shell simple; the siphuncle simple, central, sub-central, or near the concavity of the curved shells.*

SUB-FAMILY I. NAUTILIDÆ PROPER.—Body-chamber capacious; aperture of the shell simple; siphuncle central or internal. The genera of this sub-family are *Nautilus*, *Lituites*, *Trochoceras*, and *Clymenia;* of which the last three are exclusively Palæozoic, whilst the first ranges through all the great formations from the Silurian upwards, and is represented at the present day by the Pearly Nautilus.

In the genus *Nautilus* (fig. 250) the shell is involute or discoidal, consisting of a few whorls coiled into a flat spiral. The

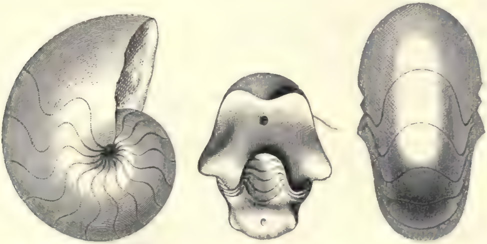


Fig. 250.—*Nautilus Danicus*. Upper Cretaceous ("Danien" of D'Orbigny).

body-chamber is of large size, and the siphuncle is central, or nearly so. The genus *Nautilus* ranges from the Upper Silu-

rian to the present day, having its maximum of development in the Carboniferous period. The Palæozoic forms are mostly discoidal, having the whorls more or less completely exposed. The *Nautili* of later deposits are mostly like the living species in having each whorl overlapping the preceding, so that merely an "umbilicus" is visible. Many of the extinct forms, belonging to all ages, agree with the living Nautilus in having the surface quite smooth (*Lævigati*). Others, which are especially characteristic of the Jurassic Rocks, have the surface striated (*Striati*). Others, chiefly of Cretaceous age, have the surface marked by distinct ribs (*Radiati*).

Fig. 251.—*Lituites cornu-arietis.* Lower Silurian.

In the Upper Silurian and Devonian Rocks *Nautili* are few; in the Carboniferous, many species are known; in the Permian Rocks and Trias are but few species; but the Jurassic and Cretaceous Rocks have yielded a considerable number. Lastly, several Tertiary species are known, all of which agree with the living *Nautilus pompilius* in having their surface completely smooth.

Fig. 252.—*Clymenia Sedgwickii.* Devonian. The lower figure shows the form of the suture.

In the genus *Lituites* (fig. 251) the shell is at first coiled discoidally with close or disconnected whorls; but the last chamber is produced into a straight or slightly-curved line. The siphuncle is placed in the centre of the septa of the shell. All the known species of *Lituites* are confined to the Silurian formation; but some occur in deposits the age of which is probably Upper Cambrian.

The genus *Trochoceras* is one which was founded by M. Barrande to include certain singular Silurian Cephalopods in which the shell is doubly curved. In the typical forms—corresponding with *Turrilites* amongst the *Ammonitidæ*—the coils of the shell are in contact and pass obliquely round a central axis, so that the shell becomes turreted. In other cases, however, the shells are simply bent, and we have an approach to the genus *Cyrtoceras*.

In the genus *Clymenia* (fig. 252) the shell is discoidal, coiled into a flat spiral, and closely resembling some of the older forms of *Nautilus*. The inner side of each whorl is deeply excavated for the reception of the convexity of the internal whorl. The septa are simple, like those of *Nautilus*, or are slightly lobed, and the siphuncle is *internal*, placed on the concave side of the whorls. Numerous species of *Clymenia* are known, all belonging to the Devonian period; and some of the Upper Devonian limestones of Germany are so profusely charged with fossils of this genus as to have received the name of "Clymenien-kalk."

SUB-FAMILY 2. ORTHOCERATIDÆ.—Shell straight, curved, or discoidal; body-chamber small; aperture of the shell small, sometimes extremely contracted; siphuncle complicated. The *Orthoceratidæ* commence in the lowest Silurian deposits, and attain their maximum of development in the Silurian Rocks. The family is well represented in the Devonian and Carboniferous Rocks, but is much reduced in numbers in the Permians. The last appearance of the family is in the Triassic Rocks, where it is represented by the genera *Orthoceras* and *Cyrtoceras*. The chief genera of this sub-family are *Orthoceras*, *Gomphoceras*, *Phragmoceras*, *Cyrtoceras*, *Gyroceras*, and *Ascoceras*.

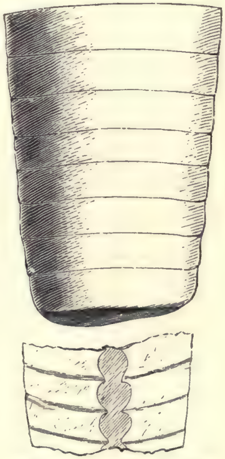


Fig. 253. — *Orthoceras crebriseptum*. Lower Silurian. The lower figure is a section, showing the form and position of the siphuncle.

In the genus *Orthoceras* (fig. 253) the shell is straight, the siphuncle central or excentric, often of a very complex structure, and the aperture of the shell sometimes contracted. The

Orthocerata are pre-eminently fossils of the Silurian, Devonian, and Carboniferous Rocks. They are, however, found in the Permians, and, passing into the Mesozoic series, they make their last appearance near the summit of the Triassic Rocks. They sometimes attained an enormous size, occasionally exceeding six feet in length, with a diameter of more than a foot. Some idea of the vast numbers of these Cephalopods in the Palæozoic seas may be obtained from the statement that M. Barrande enumerates more than five hundred species as occurring in the small Silurian basin of Bohemia alone. The numerous species of *Orthoceras* are divided by the above-named distinguished palæontologist into two principal sections—the Short-coned Orthoceratites, and the Long-coned Orthoceratites—according as the shell has the form of a short cone with a large apical angle, or of a prolonged cone with a small apical angle. The first of these groups is a very small one, and almost all the more common forms come into the second group.

The nature of the siphuncle is very different in different *Orthocerata*, and more or less well marked sub-genera have been founded upon the characters of this structure. In the sub-genus *Huronia* the siphuncle is of very large size, each joint being cylindrical below but inflated above, the outer walls of the siphuncle being connected with an internal central tube by radiating plates. In the forms termed *Cochleati* the siphuncle consists of a succession of spheroidal bead-like joints. In the sub-genus *Endoceras* the siphuncle is very large, marginal, excentric, or central, and it is partitioned off by funnel-shaped diaphragms. There is, however, considerable difference of opinion as to the true nature of the siphuncle in this sub-genus. Lastly, in the sub-genus *Gonioceras* the transverse section of the shell is flattened, and the sutures are undulated.

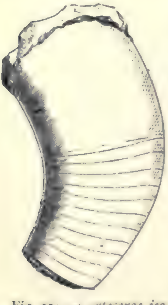


Fig. 254.—*Cyrtoceras isodorus* (Billings). Lower Silurian.

The genus *Cyrtoceras* (fig. 254) very closely resembles *Orthoceras*, but the shell is curved instead of being straight, and the siphuncle is either sub-central, or is more commonly *internal—i.e.*, on the concave side of the shell. *Cyrtoceras* has about the same vertical range as *Orthoceras*, ranging from the Silurian through all the Palæozoic formations, and disappearing in the Trias. The genus is characteristically Silurian, and M. Barrande has

described nearly two hundred and fifty species from rocks of this age in Bohemia.

Fig. 255.—*Phragmoceras* (*Campulites*) *ventricosus*. Upper Silurian. The right-hand figure shows the form of the aperture.

In the genus *Phragmoceras* (fig. 255) the shell is curved, and its aperture is contracted in the most extraordinary manner in the middle, so as to assume somewhat of the shape of a keyhole. The siphuncle in the majority of cases is placed upon the concave side of the shell. In other cases, the ventral side of the Mollusc corresponds with the convex side of the shell. The species of *Phragmoceras* are Silurian and Devonian, mainly the former; and M. Barrande enumerates thirty-eight species as occurring in the Silurian basin of Bohemia.

Fig. 256. — *Ascoceras Canadensis* (Billings), showing the form of the septa. Lower Silurian.

In the genus *Gomphoceras*, the shell is spindle-shaped, or globular, tapering towards its apex. The aperture is contracted in the middle, like that of *Phragmoceras*, and the siphuncle is generally sub-central. In most cases the ventral

side of the shell is relatively the most convex, but the reverse of this sometimes occurs. The species of *Gomphoceras* range from the Silurian to the Carboniferous, but belong mainly to the former. M. Barrande enumerates no less than seventy-three species as occurring in the Silurian Rocks of Bohemia.

The genus *Ascoceras* (fig. 256) comprises some singular forms in which the shell is globular or flask-shaped, and the septa do not run at right angles to the axis of the shell, but nearly parallel with it, being at the same time curved in an extraordinary manner. The air-chambers also are restricted to a portion only of the shell. In *Aphragmites* the air-chambers are not persistent. Both these genera are exclusively confined to the Silurian Rocks, abounding chiefly in the upper division of the series.

Lastly, in the genus *Gyroceras* the shell is coiled into a flat spiral, the volutions of which are not contiguous. The siphuncle is excentric. This genus is, perhaps, hardly separated from *Lituites* by any sufficiently good characters. The species of the genus are mainly Upper Silurian and Devonian.

AMMONITIDÆ.

FAM. II. AMMONITIDÆ.—*Shell discoidal, curved, spiral, or straight; body-chamber elongated; aperture guarded by processes, or closed by an operculum; sutures angulated, lobed, or foliaceous; siphuncle external or dorsal, on the convex side of the curved shells.*

The chief point by which the *Ammonitidæ* are distinguished from the *Nautilidæ* is the nature of the septa between the air-chambers. The latter have septa which are simply curved, and which consequently exhibit plain or very slightly lobed edges or sutures. In the *Ammonitidæ*, on the other hand, the septa are "nearly flat in the middle, and folded round the edge (like a shirt-frill), where they abut against the outer shell-wall" (Woodward). The result of this is that the "sutures" or edges of the septa appear on the surface of the shell in the form of angulated, lobed, or foliaceous lines (fig. 257).

The angulated or digitated portions of the suture, which are directed inwards, away from the mouth of the shell, are called the "*lobes*." The elevations between the "lobes," which point towards the mouth of the shell, are called the "*saddles*." These parts have the following arrangement (fig. 257):—In the middle of the back or convex surface of the shell, traversed by the siphuncle, is a single unpaired lobe which is termed the "dorsal lobe" (D). The lobe on each side of this is the "lateral-superior" lobe (L). The lobe next to this

again is the "lateral-inferior" lobe; and the lobes which follow this (of a variable number) are the "auxiliary" lobes (A^1, A^2, A^3, A^4). Lastly, there is a second unpaired lobe immediately opposite to the dorsal lobe, placed upon the concave side of the shell, and termed the "ventral" lobe. The "saddles" are similarly subdivided. Between the dorsal and lateral-superior lobes comes the "dorsal saddle" (SD). Next to this, between the superior-lateral and inferior-lateral lobes is placed the "lateral saddle" (SL) on each side; and this is followed by a variable number of "auxiliary saddles" (S^1, S^2, S^3, S^4).

Fig. 257.—One-half of the suture of *Ammonites Truellii.* D, Dorsal lobe, traversed by the siphuncle; L, Lateral-superior lobe; E, Lateral-inferior lobe; A^1, A^2, A^3, A^4, Auxiliary lobes; SD, Dorsal saddle; SL, Lateral saddle; S^1, S^2, S^3, S^4, Auxiliary saddles.

The aperture of the shell in the *Ammonitidæ* is commonly furnished with lateral processes of greater or less length; and in some, if not in all cases, it was further protected by a horny or shelly operculum. Sometimes the operculum consists of a single piece: but in other cases it is divided into two symmetrical halves by a straight median suture. The opercula of this latter kind were originally described as separate fossils, under the name of *Trigonellites.*

As regards the general distribution in time of the *Ammonitidæ*, the earliest-known forms of the group appear in the Silurian Rocks; the genus *Bactrites* in the Lower Silurian, and *Goniatites* in the Upper Silurian. No other Palæozoic types of the group are known; but with the commencement of the Mesozoic period begins an era in which an enormous development of the *Ammonitidæ* took place. The genus *Ceratites* is characteristically Triassic. The Jurassic Rocks are chiefly distinguished by species of the genus *Ammonites* itself, though other generic types are not wanting. Lastly, in the Cretaceous Rocks we find, along with *Ammonites* proper,

several remarkable forms, such as *Turrilites*, *Baculites*, *Hamites*, *Scaphites*, and *Ptychoceras*. With the close of the Cretaceous period the *Ammonitidæ* disappeared altogether, and no example of this large and varied family has as yet been detected in the Tertiaries, or is known to exist in Recent seas.

Genera of Ammonitidæ.

The genus *Goniatites* (fig. 258) comprises ancient forms of the Ammonitidæ, in which the shell is discoidal; the sutures are simply lobed or angulated; and the siphuncle is dorsal. The earliest-known forms of this genus are found in the Upper Silurian Rocks, the last in the Trias, and the most in the Carboniferous.

The genus *Bactrites* comprises forms quite similar to *Goniatites*, except that the shell, instead of being rolled up, is straight. The genus *represents Orthoceras*, from which it differs in the

Fig. 258.—*Goniatites* (*Aganides*) *Jossæ*. Carboniferous.

possession of lobed septa, and in the position of the siphuncle. The known species range from the Lower Silurian to the Devonian.

The genus *Ceratites* (fig. 259) comprises forms which re-

semble *Goniatites* in having a discoidal shell, the coils of which lie in one plane and are contiguous. It is distinguished, however, from *Goniatites* on the one hand and *Ammonites* on the other, by having the "lobes" of the suture denticulated or crenulated, whilst the "saddles" are simply rounded. The species of *Ceratites* are typically Triassic, the best-known form being the *C. nodosus* of the Muschelkalk. Some species, however, occur in the Cretaceous Rocks, though no member of the genus has as yet been detected in the intervening Jurassic deposits.

Fig. 259.—*Ceratites nodosus.* Muschelkalk (Middle Trias).

The genus *Ammonites* comprises by far the greater number of the *Ammonitidæ*, over five hundred species being already known. The shell in *Ammonites* is spirally rolled up into a flat spiral, all the volutions of which are contiguous (figs. 260, 261). The innermost whorls of the shell are more or less concealed; the septa are undulated; the sutures are lobed, foliaceous, or ramified; and the siphuncle is dorsal. The species of the genus *Ammonites* range from the Trias to the

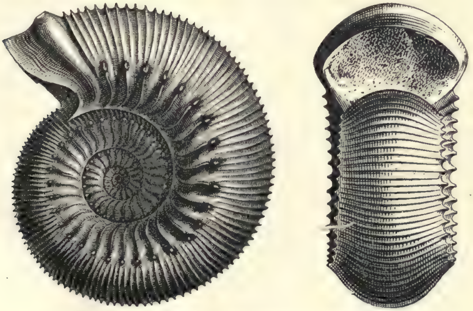


Fig. 260.—*Ammonites Humphresianus.* Inferior Oolite.

Chalk, and are thus exclusively confined to the Secondary period. Within these limits, each rock-group is characterised by particular species, the number of individuals being often very great, and the size which is sometimes attained being nothing short of

Fig. 261.—*Ammonites bifrons*. Lias.

gigantic. In the Lias particular species of *Ammonites* succeed one another regularly, each having its own definite horizon, which it does not transgress. It is thus possible to distinguish a certain number of zones, each characterised by a particular Ammonite. Some of these zones are very persistent and extend over very wide areas, thus affording valuable aid to the geologist in his determination of rocks. It is to be remembered, however, that there are other species which are not thus restricted in their vertical range, even in the same formations in which definite zones occur.

The numerous species of *Ammonites* are divided into groups as follows (Pictet) :—

SECTION A. *Back with an entire keel.*

1. *Arietes* . . . Lower Oolites.—*Ex.* A. bisulcatus.
2. *Falciferi* . . Lower Oolites.—*Ex.* A. serpentinus.
3. *Cristati* . . . Cretaceous.—*Ex.* A. inflatus.

SECTION B. *Back crenated or tuberculated.*

4. *Amalthei* . . Oolites.—*Ex.* A. cordatus.
5. *Pulchelli* (or *Rhotomagenses*) . . Cretaceous.—*Ex.* A. crenatus.

SECTION C. *Back compressed and sharp.*

6. *Clypeiformi* (or *Disci*) . . . Oolites.—*Ex.* A. discus.

SECTION D. *Back channelled.*

7. *Dentati*	. . .	Oolitic and Cretaceous.—*Ex.* A. Jason.
8. *Gemmati*	. . .	Trias.—*Ex.* A. Aon.

SECTION E. *Back squared.*

9. *Flexuosi*	. . .	Cretaceous.—*Ex.* A. radiatus.
10. *Compressi*	. .	Cretaceous.—*Ex.* A. Beaumontianus.
11. *Armati*	. . .	Oolitic.—*Ex.* A. perarmatus.
12. *Angulicostati*	.	Oolitic and Cretaceous—*Ex.* A. Milletianus.

SECTION F. *Back round.*

13. *Capricorni*	. . .	Lias.—*Ex.* A. planicostatus.
14. *Heterophylli*	. .	Oolitic.—*Ex.* A. heterophyllus.
15. *Ligati*	. . . .	Cretaceous.—*Ex.* A. Mayorianus.
16. *Planulati*	. . .	Oolitic.—*Ex.* A. annulatus.
17. *Coronati*	. . .	Oolitic.—*Ex.* A. Humphresianus.
18. *Macrocephali*	. .	Oolitic and Cretaceous.—*Ex.* A. microstoma.
19. *Globosi*	. . .	Trias.—*Ex.* A. globus.
20. *Fimbriati*	. .	Jurassic and Cretaceous.—*Ex.* A. sub-fimbriatus.

In the genus *Crioceras* are included forms which resemble the Ammonites in all essential characters, but in which the volutions of the shell are not contiguous. The shell, therefore, is discoidal, with separate whorls, thus corresponding with *Gyroceras* amongst the series of the *Nautilidæ.* All the known species of *Crioceras* belong to the Cretaceous period, ranging from the Lower Greensand to the Gault.

In the genus *Toxoceras* the shell is simply arcuate, or bent like a horn, and is never spirally rolled up; so that this genus represents *Cyrtoceras* in the series of the *Nautilidæ.* The species of *Toxoceras* range from the lower Oolites to the Gault, but the genus is characteristically Cretaceous.

In the genus *Ancyloceras* (fig. 262) the shell at first re-

Fig. 262.—*Ancyloceras Matheronianus.* Gault.

sembles that of *Crioceras*, consisting of several volutions which are coiled into a flat spiral, but which are not in contact with one another. The shell differs from *Crioceras*, however, in the fact that the last volution is produced at a tangent, and is ulti-

mately bent back in the form of a crosier. The species of *Ancyloceras* are Jurassic and Cretaceous, ranging from the Inferior Oolite to the Chalk.

In the genus *Scaphites*, the shell resembles that of *Ancyloceras* in consisting of a series of volutions coiled into a flat spiral, and having the last volution detached from the others, produced, and ultimately bent back in the form of a crosier. *Scaphites* differs from *Ancyloceras* in the fact that the volutions of the enrolled part of the shell are in contact, instead of being separate as they are in the latter. The produced whorl, also, is rarely of any great length, but is speedily bent back upon itself. All the species of *Scaphites* are Cretaceous, ranging from the Lower Greensand to the Chalk.

In the genus *Helicoceras* the shell is coiled into a turreted spiral, the volutions of which are not contiguous. The shell is, also, left-handed or "sinistral." With the exception of a single species from the Inferior Oolite, all the species of *Helicoceras* belong to the Cretaceous period.

In the genus *Turrilites* the shell agrees with that of the preceding in being composed of volutions which pass obliquely round a central axis (fig. 263), so as to form a turreted spiral. The shell is, also, left-handed or "sinistral." In *Turrilites*, however, the whorls of the shell are in contact, instead of being disconnected as they are in *Helicoceras*. The genus corresponds with *Trochoceras* in the series of the *Nautilidæ*. All the species of *Turrilites* are Cretaceous, ranging from the Gault to the Chalk.

Fig. 263.—*Turrilites catenatus*. Gault.

In the genus *Hamites* the shell is an extremely-elongated cone, which is bent upon itself more than once, in a hook-like manner, all the volutions being separate. Numerous species of *Hamites* are known, all of them being Cretaceous, and ranging from the Lower Greensand to the Chalk.

In the genus *Ptychoceras* the shell is, also, a much elongated cone, which is simply bent upon itself once, the two straight portions of the shell being in contact. The range of this genus is the same as that of *Hamites*, extending from the Lower Greensand to the Chalk.

Lastly, in the genus *Baculites* the shell is simply a straight elongated cone, not bent in any way. *Baculites* corresponds, therefore, with *Orthoceras* in the series of the *Nautilidæ*. The range of *Baculites* is the same as that of the preceding—from the Lower Greensand to the Chalk; but the genus is most abundant in the Chalk itself.

CHAPTER XXVI.

DIBRANCHIATE CEPHALOPODS.

THE Dibranchiate Cephalopods or Cuttle-fishes are characterised as being *swimming animals, almost invariably naked, with never more than eight or ten arms, which are always provided with suckers. There are two branchiæ, which are furnished with branchial hearts; an ink-sac is always present; the funnel is a complete tube, and the shell is internal, or, if external, is not chambered.*

The Cuttle-fishes are rapacious and active animals, swimming freely by means of the jet of water expelled from the funnel. The arms constitute powerful offensive weapons, being excessively tenacious in their hold, and being sometimes provided with a sharp claw in the centre of each sucker. They are mostly nocturnal or crepuscular animals, and they sometimes attain to a great size. They may be divided into two sections, *Octopoda* and *Decapoda*, according as they have simply eight arms, or eight arms and two additional "tentacles."

The parts of a Dibranchiate Cephalopod which may be preserved in a fossil condition are the mandibles, the ink-sac, the shell (if such be present), and the internal skeleton. The occurrence of the mandibles and ink-sacs of Dibranchiate Cephalopods in a fossil state has been already spoken of (p. 273), and need not be further noticed here. An external shell is present only in the Argonaut amongst living Cuttle-fishes, and similar structures are of rare occurrence as fossils in some of the youngest portions of the earth's crust. The internal skeleton of the Cuttle-fishes differs very much in its characters

in different cases. In the Calamaries the skeleton is in the form of a horny "pen," consisting of a median shaft and of two lateral expansions or wings. In the *Sepiadæ* the skeleton has the form of a broad, laminated, calcareous plate, having a more or less perfectly chambered apex or "mucro." In the singular *Spirula* the skeleton has the form of a chambered tube coiled into a spiral, the coils of which are separate from one another. Lastly, in the extinct family of the *Belemnitidæ*, there was a complicated internal support. It is, then, chiefly from the preservation of their internal skeletons that the Dibranchiate Cephalopods are known to have existed in past periods of the earth's history. In addition, however, to the skeleton, mandibles, and ink-bag, cases are not altogether unknown in which the hooks of the suckers, and even the outlines of the arms and body, have been preserved in a fossil condition.

As regards their general distribution in time, the record of the Dibranchiate Cephalopods is much less complete than that of the *Tetrabranchiata*. In the vast series of the Palæozoic formations no trace has ever been discovered of the existence of any member of this order. Shortly after the commencement of the Mesozoic period appear the first Belemnites; and all the Secondary formations after the oldest teem with the remains of this family of the *Dibranchiata*. Remains of the living families of the *Teuthidæ* and *Sepiadæ* are also not unknown in the Mesozoic Rocks, but no trace of the great group of the *Belemnitidæ* has hitherto been detected in Tertiary deposits. Upon the whole, the order must be regarded as having attained its maximum at the present day. In the following are given the characters, chief genera, and distribution in time of the families of the Dibranchiate Cephalopods.

SECTION A. OCTOPODA.—The Cephalopods comprised in this section are distinguished by the possession of eight arms, which are provided with sessile suckers. The body is short and bursiform, ordinarily without fins. The shell is internal and rudimentary; in one instance only (Argonaut) external.

FAM. 1. ARGONAUTIDÆ.—Female provided with a delicate, symmetrical, involuted shell, which is secreted by the webbed extremities of the two dorsal arms, and is not attached in any way to the body of the animal. Male much smaller than the female, shell-less. This family includes only the single genus *Argonauta* (the Paper Nautilus). One or two species of Argonaut have been discovered in the Pliocene Tertiary.

FAM. 2. OCTOPODIDÆ.—Shell internal, rudimentary, represented by two short styles encysted in the substance of the

mantle. This family includes the living Poulpes and their allies, but has no fossil representatives.

SECTION B. DECAPODA.—The Cuttle-fishes of this section have eight "arms" and two additional "tentacles," which are much longer than the true arms, and carry suckers on their extremities only, which are expanded and club-shaped. The suckers are pedunculated, the body is furnished with lateral fins, and the shell is always internal.

FAM. 3. TEUTHIDÆ.—Shell consisting of an internal horny "pen" or "gladius," composed of a central shaft and two lateral wings. Several of such pens may exist in a single individual, packed one behind the other. Fins mostly terminal and angular. This family comprises the living Calamaries and Squids, and the following fossil genera have been founded upon "pens" which have been discovered in various Secondary deposits.

a. Teudopsis.—Pen lanceolate, produced in front, dilated and spatulate behind. Five species of this genus have been described from the Lias.

b. Beloteuthis.—Pen lanceolate, pointed in front, with two small wing-like expansions behind (fig. 264). Six species have been described by Count Münster from the Upper Lias of Würtemberg.

Fig. 264.—*Beloteuthis subcostata.* Jurassic (Lias).

c. Leptoteuthis.—Pen horny, hastate, broad in front, pointed behind. A single species is known from the Oxford Clay (Jurassic).

d. Besides the above, remains found in the Jurassic Rocks have been referred to the living genera *Enoploteuthis* and *Ommastrephes;* and the extinct genus *Acanthoteuthis* has also been placed in this family.

FAM. 4. SEPIADÆ.—Internal skeleton in the form of a broad, laminated, calcareous plate, with an imperfectly-chambered apex (or "mucro"). The chambered portion of the skeleton corresponds with the "phragmacone" of the Belemnites. The fossil species of this family range from the Middle Oolites upwards, and belong to the following three genera :—

a. Sepia.—Shell broad and thick in front, laminated, and terminating in a prominent mucro. The fossil forms belong to the Oxford Clay (Jurassic) and Eocene Tertiary, and the genus attains its maximum at the present day.

b. Spirulirostra.—The shell (fig. 265) in this singular genus consists of a chambered portion or phragmacone coiled into a spiral, the volutions of which are separated. This is lodged in a pointed calcareous portion or "rostrum." The only known species of this genus is found in the Miocene Tertiary.

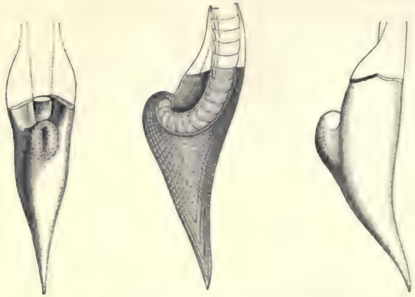


Fig. 265.—*Spirulirostra Bellardii.* Miocene Tertiary.

c. Beloptera.—Shell consisting of a nearly straight chambered portion or "phragmacone," perforated by a siphuncle, and lodged in a pointed calcareous rostrum which is furnished with lateral wings. Two species only of this genus are known, both from the Eocene Tertiary.

d. Belemnosis.—This genus has been founded for the reception of an Eocene fossil closely resembling *Beloptera*, but differing in not possessing any lateral expansions.

FAM. 5. SPIRULIDÆ.—Shell nacreous, discoidal, composed of volutions which are not in contact with one another. The shell is divided into a series of air-chambers by curved shelly partitions, pierced by a ventral tube or "siphuncle." The entire shell corresponds with the "phragmacone" of the skeleton of the Belemnites. *Spirulirostra* and *Beloptera* are often referred to this family; but if these be placed in the *Sepiadæ*, the family of the *Spirulidæ* is then without any known fossil representative.

FAM. 6. BELEMNITIDÆ.—Shell internal, composed of a conical chambered portion ("phragmacone"), with a marginal or ventral siphuncle, lodged in a cylindrical fibrous "guard," and produced in front into a thin horny or shelly plate or "pen" (the "pro-ostracum"). The *Belemnitidæ* are exclusively confined to the Secondary Rocks, ranging from the top of the

Trias to the Chalk. The following are the more important genera belonging to this family:—

a. Belemnites.—The skeleton of the Belemnite consists of a sub-cylindrical, longer or shorter, fibrous body (fig. 266), which is termed the "rostrum" or "guard." The length of the guard varies very much in different cases, and it is the part of the Belemnite which is most commonly found in a fossil condition. At the front or broad end, the guard is hollowed out into a conical excavation, which is termed the "alveolus." Within the alveolus, in perfect specimens, is contained the "phragmacone." This consists of a conical series of chambers, separated from one another by curved shelly partitions or septa, which are perforated by apertures for the passage of the "siphuncle." The siphuncle traverses the middle of the ventral wall of the phragmacone, and the whole series of chambers is enclosed in a thin shell-wall (the "conotheca" of Huxley). Anteriorly the conotheca or investment of the phragmacone is prolonged forwards into a horny or shelly plate, which corresponds with part of the "pen" of the Calamaries, and which is termed the "pro-ostracum" (fig. 266, *r*). The form of the "pro-ostracum" varies greatly in different cases, and it affords important characters in the discrimination of specific and generic forms in the *Belemnitidæ*. Owing, however, to its extreme tenuity, it is very rarely found preserved in a fossil condition, and its value to the working palæontologist is thus greatly reduced.

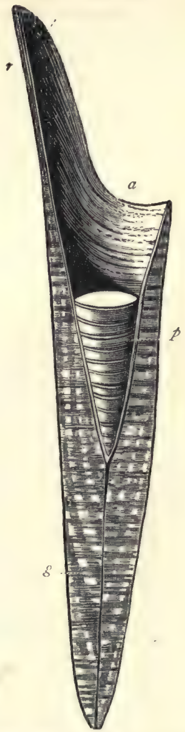


Fig. 266.—Diagram of Belemnite (after Professor Phillips). *r* Horny or shelly pen or "pro-ostracum;" *p* Chambered "phragmacone" in its cavity (*a*) or "alveolus;" *g* "Guard."

Not only is the internal skeleton of the Belemnite known, but various specimens have been discovered, from which much has been learnt as to other points

of its anatomy. Thus we know that the body was furnished with lateral fins, that there were eight arms and two longer "tentacles," that the suckers were provided with horny hooks, that there was a large ink-sac, and that the mouth was armed with horny mandibles.

The following table of the sections and sub-sections of the species of the genus *Belemnites* is the one given by Dr S. P. Woodward :—

Section I. Accœli.
Without dorsal or ventral grooves.
Sub-section 1. *Acuarii.*
Without lateral furrows, but often channelled at the extreme point. (*Ex. B. acuarius.* Lias.)
Sub-section 2. *Clavati.*
With lateral furrows. (*Ex. B. clavatus.* Lias.)
Section II. Gastrocœli.
Ventral groove distinct.
Sub-section 1. *Canaliculati.*
No lateral furrows. (*Ex. B. canaliculatus.* Inf. Oolite.)
Sub-section 2. *Hastati.*
Lateral furrows distinct. (*Ex. B. hastatus.* Oolite.)
Section III. Notocœli.
With a dorsal groove, and furrowed on each side. (*Ex. B. dilatatus.* Neocomian.)

The species of the genus *Belemnites* range from the top of the Trias, where the earliest forms appear, to the Upper Greensand, in which the genus finally disappears. The species are most numerous in the Jurassic Rocks, and often occur in the greatest abundance in particular beds or particular localities. It would seem not improbable that the genus *Beloptera*, before noticed, should be referred to the *Belemnitidæ*, and the genus *Belemnosepia* (or *Geoteuthis*), formerly referred to the *Teuthidæ*, appears to be almost certainly referable here.

Fig. 267.—*Belemnitella mucronata.* Chalk.

b. Belemnitella.—In this genus (fig. 267) the skeleton is very similar in its general arrangement to that of *Belemnites ;* but there is a straight fissure in the guard, at its upper end, on the ventral side of the wall of the alveolus. The species of this genus are exclusively Cretaceous, and are only found in the upper portion of this formation, ranging from the Upper Greensand to the Chalk.

c. Belemnoteuthis.—"*Shell* consisting of a *phragmacone*, like that of the Belemnite; a horny dorsal *pen* with obscure lateral bands; and a thin fibrous *guard*, with two diverging ridges on the dorsal side. *Animal* provided with

arms and *tentacles* of nearly equal length, furnished with a double alternating series of horny hooks, from 20 to 40 pairs on each arm ; *mantle* free all round ; *fins* large, medio-dorsal." —(Woodward.) Only one species is known, from the Oxford Clay (Middle Oolites). High authorities, such as Owen and D'Orbigny, question the validity of this genus, and regard it as being founded upon specimens of *Belemnites*.

d. Xiphoteuthis.—Guard narrow and cylindrical, containing a very long, deep-chambered, narrow phragmacone. Pro-ostracum greatly developed (nearly a foot in length), very narrow at its base, widening out anteriorly, and finally terminating in a pointed apex. Only a single species is known, from the Lias.

CHAPTER XXVII.

SUB-KINGDOM VERTEBRATA.

THE sub-kingdom *Vertebrata* may be shortly defined as including *animals in which the body is composed of a succession of definite segments, arranged along a longitudinal axis; the main masses of the nervous system (brain and spinal cord) are situated along the dorsal surface of the body, and are completely shut off from the general body-cavity. The limbs are never more than four in number, and are always turned away from that aspect of the body upon which the main masses of the nervous system are situated. In all, the nervous axis is primitively supported by a cellular rod, which is termed the "notochord;" but in most the notochord is replaced in the adult by the bony axis known as the "spine" or "vertebral column."*

The past existence of Vertebrate animals is chiefly recognised by the preservation of their hard structures. These hard structures are of two kinds—some belonging to the internal or true skeleton (endoskeleton), others being of the nature of horny or bony plates, scales, or appendages of various kinds, developed in the integument (exoskeleton). The nature of the exoskeleton in the Vertebrates differs very much in different cases, and it will be considered when treating of the separate groups. It will be well, however, to give an extremely general and brief view of the structure of the endoskeleton, taking for this purpose a Mammal as a typical form. In this way the student will be enabled readily to trace the modifications of the skeleton in the lower forms, and will without

difficulty comprehend the terms which are necessarily employed in the definitions of the various groups. It may be added here, before proceeding further, that it does not seem requisite to treat the *Vertebrata* with the same fulness as the *Invertebrata*. The fossil remains of Vertebrates are in many cases of the highest theoretical interest, but they come much less frequently under the notice of the ordinary student than do the remains of the Invertebrates. No practical study, also, of the fossil Vertebrates can be carried out without a considerable acquaintance with Comparative Osteology. Lastly, the remains of Vertebrate animals generally occur in such a fragmentary condition that a sufficient series of specimens for profitable study can rarely be obtained, except under peculiarly favourable circumstances, in special cases, or where access can be had to a first-rate museum. For these and other reasons it is thought enough, in a treatise intended for the working palæontologist, to give a general account of each class of the *Vertebrata*, with definitions of the orders, and a brief notice of the leading forms of each. Only in cases of special interest will any details of a more minute character than the above be given.

The *skeleton* of the *Vertebrata* may be regarded as consisting essentially of the bones which go to form the head and trunk on the one hand (sometimes called the "axial" skeleton), and of those which form the supports for the limbs ("appendicular" skeleton) on the other hand. The bones of the head and trunk may be looked upon as essentially composed of a series of bony rings or segments, arranged longitudinally, one behind the other. Anteriorly these segments are much expanded, and likewise much modified, to form the bony case which encloses the brain, and which is termed the *cranium* or skull. Behind the head the segments enclose a much smaller cavity, which is called the "neural" or spinal canal, as it encloses the spinal cord; and they are arranged one behind the other, forming the vertebral column. The segments which form the vertebral column are called "vertebræ," and they have the following general structure:—Each vertebra (fig. 268, A) consists of a central piece, which is the fundamental and essential element of the vertebra, and is known as the "body" or "centrum" (*c*). From the upper or posterior surface of the centrum spring two bony arches (*n n*), which are called the "neural arches" or "neurapophyses," because they form with the body a canal—the "neural canal"—which encloses the spinal cord. From the point where the neural arches meet behind, there is usually developed a longer or shorter spine, which is termed the "spinous process" or "neural spine" (*s*). From the neural arches

there are also developed in the typical vertebra two processes (*a a*), which are known as the "articular" processes, or "zygapophyses." The vertebræ are united to one another partly by these, but to a greater extent by the bodies or "centra." From the sides of the vertebral body, at the point of junction with the neural arches, there proceed two lateral processes (*d d*), which are known as the "transverse processes."

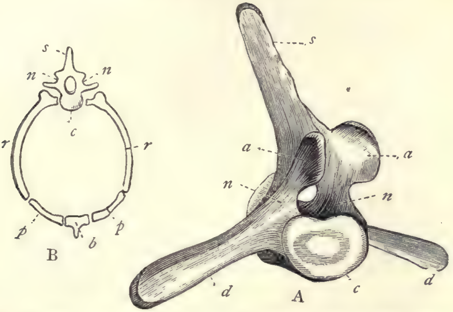


Fig. 268.—A, Lumbar vertebra of a Whale: *c* Body or centrum; *n n* Neural arches; *s* Neural spine; *a a* Articular processes; *d d* Transverse processes. B, Diagram of a thoracic vertebra: *c* Centrum; *n n* Neural arches enclosing the neural canal; *s* Neural spine; *r r* Ribs, assisting in the formation of the hæmal arch; *p p* Costal cartilages; *b* Sternum, with hæmal spine. (After Owen.)

These elements form the *vertebra* of the human anatomist, but the "vertebra" of the transcendental anatomist is completed by a second arch which is placed beneath the body of the vertebra, and which is called the "hæmal" arch, as it includes and protects the main organs of the circulation. This second arch is often only recognisable with great difficulty, as its parts are generally much modified, but a good example may be obtained in the human chest, or in the caudal vertebra of a bony fish.

As a general rule, the vertebral column is divisible into a number of distinct regions, of which the following are recognisable in man and in the higher *Vertebrata*:—1. A series of vertebræ which compose the neck, and constitute the "cervical region" of the spine (fig. 269, *c*). 2. A number of vertebræ which usually carry well-developed ribs, and form the "dorsal region" (*d*). 3. A series of vertebræ which form the region of the loins, or "lumbar region" (*b*). 4. A greater or less number of vertebræ which constitute the "sacral region," and

are usually amalgamated or "anchylosed" together to form a single bone, the "sacrum" (*s*). 5. The spinal column is completed by a variable number of vertebræ which constitute the "caudal" region, or tail (*t*).

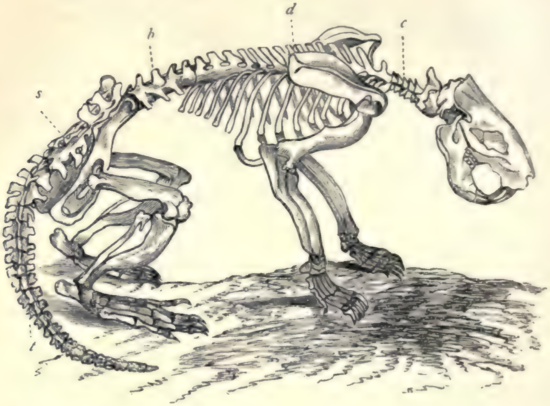


Fig. 269.—Skeleton of the Beaver (*Castor fiber*), showing the different regions of the vertebral column. *c* Cervical region; *d* Dorsal region; *b* Lumbar region; *s* Sacrum; *t* Caudal region.

As regards the skull of the Vertebrates, the most important points to be noticed are the manner in which the cranium articulates with the vertebral column, and the structure of the lower jaw or "mandible." In Birds and Reptiles the skull articulates with the first vertebra of the neck by means of a single articulating surface or "condyle," carried upon the occipital bone. In the Amphibians, again, and in the Mammals, there are *two* "occipital condyles," by which the skull is jointed to the neck. The lower jaw is sometimes wanting, but, when present, it consists in all *Vertebrata* of two halves or "rami," which are united to one another in front, and articulate separately with the skull behind. In many cases, each half, or "ramus," of the lower jaw consists of several pieces united to one another by sutures; but in the *Mammalia* each ramus consists of no more than a single piece. The two rami are very variously connected with one another, being sometimes only joined by ligaments and mus-

cles, sometimes united by cartilage or by bony suture, and sometimes fused or anchylosed with one another, so as to leave no evidence of their true composition. The mode by which each ramus of the lower jaw articulates with the skull also varies. In the *Mammalia* the lower jaw articulates with a cavity formed on what is known to human anatomists as the temporal bone; but in Birds and Reptiles, the lower jaw articulates with the skull, not directly, but by the intervention of a special bone, known as the "quadrate bone" or "*os quadratum*."

As regards the *limbs* of Vertebrates, whilst many differences exist, which will be afterwards noticed, there is a general agreement in the parts of which they are composed. As a rule, each pair of limbs is joined to the trunk by means of a series of bones which also correspond to one another in general structure. The fore-limbs, often called the "pectoral" limbs, are united with the trunk by means of a bony arch, which is called the "pectoral" or "scapular" arch; whilst the hind-limbs are similarly connected with the trunk by means of the "pelvic arch." In giving a general description of the parts which compose the limbs and their supporting arches, it will be best to take the case of a Mammal, and the departures from this type will then be readily recognised.

The pectoral or scapular arch consists usually of three bones, the "scapula" or shoulder-blade, the "coracoid," and the "clavicle" or collar-bone; but in the great majority of the Mammals, the coracoid is anchylosed with the scapula, of which it forms a mere process. The scapula or shoulder-blade (fig. 270, *s*) is usually placed outside the ribs, and it forms, either alone or in conjunction with the other bones of the shoulder-girdle, the cavity with which the upper arm is articulated. The coracoid, though rarely existing as a distinct bone in the Mammals, plays a very important part in other Vertebrates. The clavicles are often wanting, or rudimentary, and they are the least essential elements of the scapular arch. The fore-limb proper consists, firstly, of a single bone which forms the upper arm, and which is known as the *humerus* (*h*). This articulates above with the shoulder-girdle, and is followed below by the fore-arm, which consists of two bones, called the *radius* and *ulna*. Of these the *radius* is chiefly concerned with carrying the hand. The radius and ulna are followed by the bones of the wrist, which are usually composed of several bones, and constitute what is called the *carpus* (*d*). These support the bones of the root of the hand, which vary in number, but are always more or less cylindrical in shape. They constitute what is called the *metacarpus*. The bones of

the metacarpus carry the digits, which also vary in number, but are composed each of from two to three cylindrical bones, which are known as the *phalanges* (*p*).

Homologous parts are, as a rule, readily recognisable in the hind-limb. The pelvic arch, by which the hind-limb is united with the trunk, consists of three pieces—the *ilium*, *ischium*, and *pubes*—which are usually anchylosed together, and form conjointly what is known as the *innominate bone* (fig. 271, *i*). In

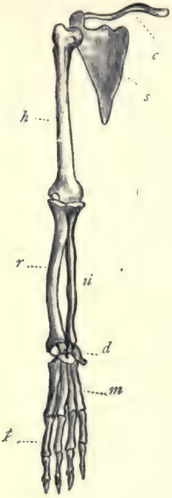


Fig. 270. — Pectoral limb (arm) of Chimpanzee. (After Owen). *c* Clavicle; *s* Scapula or shoulder-blade; *h* Humerus; *r* Radius; *u* Ulna; *d* Bones of the wrist, or carpus; *m* Metacarpus; *p* Phalanges of the fingers.

Fig. 271.—Hind-limb of the Chimpanzee. *i* Innominate bone; *f* Thigh-bone or femur; *t* Tibia; *s* Fibula; *r* Bones of the ankle, or tarsus; *m* Metatarsus; *p* Phalanges.

most Mammals, the two innominate bones unite in front by a ligamentous or cartilaginous union, and they constitute, with the sacrum, what is known as the *pelvis*. The hind-limb proper consists of the following parts:—1. The thigh-bone or *femur*, corresponding with the humerus in the fore-limb. 2.

The bones of the shank, corresponding with the radius and ulna of the fore-limb, and known as the *tibia* and *fibula*. Of these, the tibia is mainly, or altogether, concerned in carrying the foot, and it is thus shown to correspond to the radius, whilst the fibula corresponds to the ulna. 3. The small bones of the ankle, known as the *tarsus*, and varying in number in different cases. 4. A variable number of cylindrical bones (normally five), which are called the *metatarsus*, and which correspond to the metacarpus. 5. Lastly, the metatarsus carries the digits, which consist, each, of from two to three small bones or *phalanges*, as in the fore-limb.

The sub-kingdom Vertebrata is divided into the following five classes :—

1. PISCES (Fishes).—Respiration by means of gills ; heart usually two-chambered ; an exoskeleton, in the form of horny scales or bony plates, generally present; blood cold. Limbs, when present, in the form of fins, or expansions of the integument supported by bony or cartilaginous spines or "rays."

2. AMPHIBIA (Amphibians).—Respiration at first exclusively by gills, afterwards by lungs, either alone or associated with gills. Heart of the adult three-chambered ; blood cold. The skull connected with the vertebral column by two occipital condyles. The limbs, when present, never converted into fins, and composed of the same parts as in the higher Vertebrates.

3. REPTILIA (Reptiles).—Respiration aerial, by lungs, and never by gills. Pulmonary and systemic circulations connected together either within the heart or in its immediate neighbourhood. Heart of the adult three-chambered in most; rarely four-chambered. Blood cold. Skull united to the vertebral column by one occipital condyle. Exoskeleton in the form of horny scales or bony plates, or both combined.

4. AVES (Birds).—Respiration aerial, by lungs, and never by gills. Bronchial tubes opening on the surface of the lungs into air-sacs. A greater or less number of the bones almost always hollow and filled with air. The skull connected with the vertebral column by a single occipital condyle. Heart four-chambered ; the pulmonary and systemic circulations distinct, and the blood warm. Epidermic appendages in the form of feathers. Pectoral limbs in the form of wings. Animal oviparous.

5. MAMMALIA (Quadrupeds).—Respiration aerial, by lungs, and never by gills. The terminations of the air-passages (bronchi) never connected with air-sacs. Heart four-chambered ; the pulmonary and systemic circulations distinct ; the blood warm. Skull connected with the vertebral column by two articulating surfaces or condyles. Some part or other of the integu-

ment provided at some time or other with epidermic appendages in the form of hairs. The young nourished for a shorter or longer time by means of a special fluid—the milk—secreted by special glands—the mammary glands. Animal viviparous.

As regards the general *distribution in time* of the *Vertebrata*, the earliest known traces of the existence of this sub-kingdom are found in the Upper Silurian Rocks. Here are the remains of Ganoid and Plagiostomous fishes; and we may fairly anticipate that further research will ultimately result in putting back the first appearance of Fishes at any rate to the Lower Silurian. The class of the Amphibians is not known to have come into existence prior to the commencement of the Carboniferous period, but it had attained a great development before the close of this epoch. The class of the true Reptiles is represented, by more or less doubtful examples only, in the newer Palæozoic deposits. In the Mesozoic Rocks, however, the development of this class was so great that the Secondary period has been termed the "Age of Reptiles." The class *Aves* is doubtfully represented by foot-prints in strata of the age of the Trias; but no Palæozoic remains of this class have been as yet detected. The earliest undoubted remains of Birds occur in the Jurassic series, and the class has continued to be represented more or less abundantly to the present day. Lastly, the class of the *Mammalia*, so far as at present known, finds its earliest fossil representative in strata of the age of the Trias (New Red Sandstone). The Mammals, however, cannot be said to be in any way abundant as fossils, till we reach the Eocene Tertiary. From this point onward the remains of Mammals are as abundant as, in the nature of the case, they could reasonably be expected to be.

CHAPTER XXVIII.

FISHES.

THE first class of the *Vertebrata* is that of the Fishes (*Pisces*), which may be broadly defined as including *Vertebrate animals which are provided with gills throughout the whole of life; the heart, when present, consists (with one exception) of a single auricle and a single ventricle; the blood is cold; the limbs, when present, are in the form of fins, or expansions of the integument.*

In form, Fishes are adapted for rapid locomotion in water, the shape of the body being such as to give rise to the least

possible friction in swimming. To this end also, as well as for purposes of defence, the body is usually enveloped with a coating of scales developed in the inferior or dermal layer of the skin. The more important modifications in the form of these dermal scales are as follows: I. *Cycloid* scales (fig. 272), consisting of thin, flexible, horny scales, circular or elliptical in shape, and having a more or less completely smooth outline. These are the scales which are characteristic of most of the ordinary bony fishes. II. *Ctenoid* scales (fig. 273), also consisting of thin horny plates, but having their posterior margins

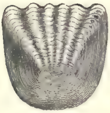


Fig. 272.—Cycloid scale.

Fig. 273.—Ctenoid scale.

Fig. 274.—Ganoid scale.

fringed with spines, or cut into comb-like projections. III. *Ganoid* scales, composed of an inferior layer consisting of bone, covered by a superficial layer of hard polished enamel (the so-called "ganoine"). These scales (fig. 274) are usually much larger and thicker than the ordinary scales, and though they are often articulated to one another by special processes, they only rarely overlap. IV. *Placoid* scales, consisting of detached bony grains, tubercles, or plates, of which the latter are not uncommonly armed with spines.

It is very important for the geologist to recognise the characters of these different scales, as he may have to decide upon the characters of a fossil fish merely from detached scales. Such decisions, however, are always more or less hazardous, since the scales of the different orders of the living fishes are not invariably of the same kind in all the forms of the order. Thus, ganoid scales are not peculiar to the order of the *Ganoid* fishes, but occur also in some of the Bony Fishes (*Teleostei*). The scales, also, form at best but one character, and they can hardly be said to constitute the most important character of any fish. A classification, therefore, which is based primarily upon the nature of the scales, necessarily is more or less "artificial," and is liable to bring into juxtaposition forms which have no real affinity to one another. For these reasons, most zoologists do not accept the classification of the Fishes into the four orders of the *Cycloidei*, *Ctenoidei*, *Ganoidei*, and *Placoidei*, since this classification, though sanctioned by such an eminent

authority as Professor Agassiz, is founded solely upon the nature of the integumentary covering. The palæontologist, however, whose materials often consist of nothing more than detached scales, is not rarely driven, by the necessity of the case, to provisionally classify his specimens in accordance with the nature of these appendages.

As regards their true osseous system or endoskeleton, Fishes vary very widely. In the Lancelet there can hardly be said to be any skeleton, the spinal cord being simply supported by the gelatinous notochord, which remains throughout life. In others the skeleton remains permanently cartilaginous; in others it is partially cartilaginous and partially ossified; and, lastly, in most modern fishes it is entirely ossified, or converted into bone. Taking a bony fish (fig. 275) as in this respect a typical example of the class, the following are the chief points in the osteology of a fish which require notice:—

The *vertebral column* in a bony fish consists of vertebræ which are hollow at both ends, or biconcave, and are technically said to be "amphicœlous." The cup-like margins of the vertebral bodies are united by ligaments, and the cavities formed between contiguous vertebræ are filled with the gelatinous remains of the notochord. This elastic gelatinous substance acts as a kind of ball-and-socket joint between the bodies of the vertebræ, thus giving the whole spine the extreme mobility which is requisite for animals living in a watery medium. The ossification of the vertebræ is often much more imperfect than the above, but in no case except that of the Bony Pike (*Lepidosteus*) is ossification carried to a greater extent than this. In this fish, however, the vertebral column is composed of "opisthocœlous" vertebræ—that is, of vertebræ the bodies of which are concave behind and convex in front. The entire spinal column is divisible into not more than two distinct regions, an *abdominal* and a *caudal region*. The abdominal vertebræ possess a superior or neural arch (through which passes the spinal cord), a superior spinous process (neural spine), and two transverse processes to which the ribs are usually attached. The caudal vertebræ (fig. 275) have no marked transverse processes; but in addition to the neural arches and spines, they give off an inferior or *hæmal* arch below the body of the vertebræ, and the hæmal arches carry inferior spinous processes (hæmal spines).

The *ribs* of a bony fish are attached to the transverse processes, or to the bodies, of the abdominal vertebræ, in the form of slender curved bones which articulate with no more than one vertebra each, and that only at a single point. Unlike the

ribs of the higher Vertebrates, the ribs do not enclose a thoracic cavity, but are simply imbedded in the muscles which bound the abdomen. Usually each rib gives off a spine-like bone, which is directed backwards amongst the muscles. Inferiorly the extremities of the ribs are free, or are rarely united to dermal ossifications in the middle line of the abdomen; but there is never any breast-bone or *sternum* properly so called.

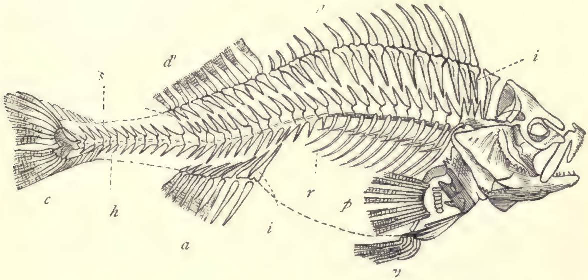


Fig. 275.—Skeleton of the common Perch (*Perca fluviatilis*). *p* Pectoral fin; *v* One of the ventral fins; *a* Anal fin, supported upon interspinous bones (*i*); *c* Caudal fin; *d* First dorsal fin; *d'* Second dorsal fin, both supported upon interspinous bones; *i i* Interspinous bones; *r* Ribs; *s* Spinous processes of vertebræ; *h* Hæmal processes of vertebræ.

The only remaining bones connected with the skeleton of the trunk are the so-called *interspinous bones* (fig. 275, *i i*). These form a series of dagger-shaped bones plunged in the middle line of the body between the great lateral muscles which make up the greater part of the body of a fish. The internal ends or points of the interspinous bones are attached by ligament to the spinous processes of the vertebræ; whilst to their outer ends are articulated the "rays" of the so-called "median" fins, which will be hereafter described. As a rule, there is only one interspinous bone to each spinous process, but in the Flat-fishes (Sole, Turbot, &c.) there are two.

Beside the fins which represent the limbs (pectoral and ventral fins), fishes possess other fins placed in the middle line of the body, and all of these alike are supported by bony spines or "rays," which are of two kinds, termed respectively "spinous rays" and "soft rays." The "spinous rays" are simple bony spines, apparently composed of a single piece each, but really consisting of two halves firmly united along the middle line. The "soft rays" are composed of several slender spines

proceeding from a common base, and all divided transversely into numerous short pieces. The soft rays occur in many fishes in different fins, but they are invariably found in the caudal fin or tail (fig. 275, *c*). The rays of the median fins, whatever their character may be, always articulate by a hinge-joint with the heads of the interspinous bones.

The *skull* of the bony fishes is an extremely complicated structure, and it is impossible to enter into its composition here. The only portions of the skull which require special mention are the bones which form the gill-cover or operculum. For reasons connected with the respiratory process in fishes, there generally exists between the head and the scapular arch a great cavity or gap on each side, within which are contained the branchiæ. The cavity thus formed opens externally on each side of the neck by a single vertical fissure or "gill-slit," closed by a broad flap, called the "gill-cover" or "operculum," and by a membrane termed the "branchiostegal membrane."

The gill-cover (fig. 276, *p*, *o*, *s*, *i*) is composed of a chain of broad flat bones, termed the opercular bones. Of these, the

Fig. 276.—Skull of Cod (*Morrhua vulgaris*)—Cuvier. *a* Urohyal; *b* Basihyal; *c* Ceratohyal; *d* Branchiostegal rays; *p* Præ-operculum; *o* Operculum proper; *s* Sub-operculum; *i* Inter-operculum; *m* Mandible; *n* Intermaxillary bone.

innermost articulates with the skull (tympano-mandibular arch), and is called the "præ-operculum;" the next is a large bone

called the "operculum" proper; and the remaining two bones, called respectively the "sub-operculum" and "inter-operculum," form, with the operculum proper, the edge of the gill-cover. These various bones are united together by membrane, and they form collectively a kind of movable door, by means of which the branchial chamber can be alternately opened and shut. Besides the gill-cover, however, the branchial chamber is closed by a membrane called the "branchiostegal membrane," which is attached to the os hyoides. The membrane is supported and spread out by a number of slender curved spines, which are attached to the lateral branches of the hyoid bone, act very much as the ribs of an umbrella, and known as the "branchiostegal rays" (fig. 276, *d*).

The *limbs* of fishes depart considerably from the typical form exhibited in the higher Vertebrates. One or both pairs of limbs may be wanting, but when present the limbs are always in the form of *fins*—that is, of expansions of the integument strengthened by bony or cartilaginous fin-rays. The anterior limbs are known as the *pectoral* fins, and the posterior as the *ventral* fins; and they are at once distinguished from the so-called "median" fins by being always disposed in pairs, usually symmetrically. Hence they are often spoken of as the *paired* fins.

The fore-limbs or pectoral fins possess in a modified form most of the bones which are present in the anterior extremities of the higher *Vertebrata*. They vary much in size and in other characters. Sometimes they are enormously expanded, as in the Flying-fish (*Exocœtus*); and at other times they form merely a pair of paddles, as in the extinct *Pterichthys*. The hind-limbs or ventral fins are wanting in many fishes, and they are less developed and less fixed in position than are the pectorals. In some cases the ventral fins are "abdominal" in position, and are placed more or less towards the hinder part of the body (as in the Sharks, Ganoids, and Mud-fishes). In other cases, they are "thoracic," that is, they are placed beneath the pectorals; and in some cases they are situated on the sides of the neck in advance of the pectorals, when they are said to be "jugular." In these cases, the pelvic arch is attached to the pectoral arch, and is therefore wholly removed from its normal position.

In addition to the pectoral and ventral fins—the homologues of the limbs—which may be wanting, fishes are furnished with certain other expansions of the integument, which are "median" in position, and must on no account be confounded with the true "paired" fins. These median fins are variable

in number, and in some cases there is but a single fringe running round the posterior extremity of the body. In all cases, however, the median fins are "azygous"—that is to say, they occupy the middle line of the body, and are not symmetrically disposed in pairs. Most commonly, the median fins consist of one or two expansions of the dorsal integument, called the "dorsal fins" (fig. 277, *d d'*); one or two on the ventral surface near the anus—the "anal fins" (fig. 277, *a*); and a broad fin at the extremity of the vertebral column, called the "caudal fin" or tail (*c*). In all cases, the rays which support the median fins are articulated with the so-called interspinous bones, which have been previously described. Though called "median," from their position in the middle line of the body, and from their being unpaired, the median fins of Fishes, as shown by Goodsir and Humphrey, are truly to be regarded as formed by the coalescence of two lateral elements in the mesial plane of the body.

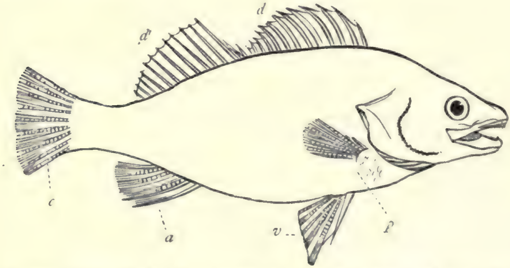


Fig. 277.—Outline of a fish (*Perca granulata*), showing the paired and unpaired fins. *p* One of the pectoral fins; *v* One of the ventral fins; *d* First dorsal fin; *d'* Second dorsal fin; *a* Anal fin; *c* Caudal fin.

The caudal fin or tail of fishes is always set vertically at the extremity of the spine, so as to work from side to side, and it is the chief organ of progression in the fishes. In its vertical position and in the possession of fin-rays, it differs altogether from the horizontal integumentary expansion which constitutes the tail of the Whales, Dolphins, and *Sirenia* (Dugong and Manatee). In the form of the tail, fishes exhibit two very distinct types of structure, termed respectively the "homocercal" and "heterocercal" type of tail (fig. 278). The homocercal tail is the one which most commonly occurs in our modern fishes, and it is characterised by the fact that the two lobes of

the tail are equal, and the vertebral column, instead of being prolonged into the upper lobe of the tail, stops short at its base. In the heterocercal tail, on the other hand, the vertebral column is prolonged into the upper lobe of the tail, so that the tail becomes unequally lobed, its greater portion being placed below the spine. Even where the vertebral column is not prolonged into the upper lobe, the tail may nevertheless become heterocercal, in consequence of a great development of the hæmal spines as compared with the neural spines of the vertebræ.

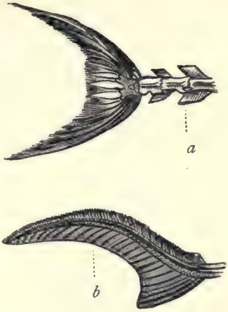


Fig. 278.—Tails of different fishes. *a* Homocercal tail (Sword-fish); *b* Heterocercal tail (Sturgeon.)

As regards their general *distribution in time*, the geological history of fishes presents some points of peculiar interest. Of all the classes of the great subkingdom *Vertebrata*, the fishes are the lowest in point of organisation. It might therefore have been reasonably expected that they would present us with the first indications of vertebrate life upon the globe; and such is indeed the case. After passing through the enormous group of deposits known as the Laurentian, Huronian, Cambrian, and Lower Silurian formations—representing an immense lapse of time during which, so far as we yet know, no vertebrate animal had been created—we find in the Upper Silurian Rocks the first traces of fish. The earliest of these, in Britain, is found in the base of the Ludlow Rocks (Lower Ludlow Shale), and belongs to the placoganoid genus *Pteraspis*. Also in the Ludlow Rocks, but at the summit of their upper division, are found fin-spines and shagreen, probably belonging to Cestraciont fishes—that is to say, to fishes of as high a grade of organisation as the *Elasmobranchii*. So abundant are the remains of fishes in the next great geological epoch—namely, the Devonian or Old Red Sandstone—that this period has frequently been designated the "Age of Fishes." Most of the fishes of the Old Red Sandstone belong to the order *Ganoidei*. In the Carboniferous and Permian Rocks, which close the Palæozoic period, most of the fishes are still Ganoid, but the former contain the remains of many Plagiostomous fishes. At the close of the Palæozoic and the commencement of the

Mesozoic epoch, the Ganoid fishes begin to lose that predominant position which they before occupied, though they continue to be represented through the whole of the Mesozoic and Kainozoic periods up to the present day. The Ganoids, therefore, are an instance of a family which has endured through the greater part of geological time, but which early attained its maximum, and has been slowly dying out ever since. Towards the close of the Mesozoic period (in the Cretaceous period) the great order of the Teleostean or Bony fishes is for the first time known certainly to have made its appearance. The orders of the *Marsipobranchii*, *Pharyngobranchii*, and *Dipnoi* have not left, so far as is known, any traces of their existence in past time. Judging from analogy, however, it is highly probable that the two former of these must have had a vast antiquity, and it is not impossible that the so-called "Conodonts" from the Lower Silurian Rocks of Russia may yet be shown to be the horny teeth of fishes allied to the Lampreys. At present, however, the weight of evidence is in favour of looking upon these problematical little bodies as probably referable to some of the *Invertebrata*.

These so-called "Conodonts" are microscopic in their dimensions, and have the form of "minute, glistening, slender, conical bodies, hollow at the base, pointed at the end, more or less bent, with sharp opposite margins" (Owen). They show no trace of dental structure, and Professor Owen concludes that they "have most analogy with the spines, or hooklets, or denticles of Naked Molluscs and Annelides."

It is also to be borne in mind that, though it has not yet been possible to definitely refer any fossil fishes to the order of the *Dipnoi*, recent discoveries have rendered it extremely probable that some well-known extinct types really belong to this order. Thus, the great "Barramunda" (*Ceratodus Fosteri*) of the rivers of Queensland would seem to be truly referable to the Triassic genus *Ceratodus*, in which case this latter must be removed to the *Dipnoi*. This remarkable fish also presents some striking points of resemblance with certain extinct Ganoids, such as *Dipterus*. Upon the whole, therefore, there are good grounds for accepting Dr. Günther's suggestion that the *Dipnoi* should be regarded as a mere sub-order of the Ganoids.

In the following chapter are given the orders of the Fishes, with the leading characters and geological distribution of each. The order, however, of the *Pharyngobranchii* (comprising only the living Lancelet), and that of the *Marsipobranchii* (comprising the Lampreys and Hag-fishes), may be here dismissed, as

they are not known to be represented by any fossil forms. There remain, therefore, for consideration the orders of the *Teleostei* (Bony Fishes), *Ganoidei* (Ganoids), *Elasmobranchii* (Sharks and Rays), and *Dipnoi* (Mud-fishes).

CHAPTER XXIX.

ORDERS OF FISHES.

ORDER I. TELEOSTEI.—This order includes the great majority of fishes in which there is a well-ossified endoskeleton, and it corresponds very nearly with Cuvier's division of the "osseous" fishes. The *Teleostei* are defined as follows:—*The skeleton is usually well ossified; the cranium is provided with cranial bones, and a mandible is present; whilst the vertebral column almost always consists of more or less completely ossified vertebræ. The pectoral arch has a clavicle; and the two pairs of limbs, when present, are in the form of fins supported by rays. The gills are free, pectinated or tufted in shape, a bony gill-cover and branchiostegal rays being always developed. The branchial artery has its base developed into a bulbus arteriosus; but this is never rhythmically contractile, and is separated from the ventricle by no more than a single row of valves.*

The scales in the Teleostean fishes are generally thin, horny, flexible plates, which overlap one another, and have the "cycloid" or "ctenoid" characters. The order, therefore, corresponds, in a general way, with the orders *Ctenoidei* and *Cycloidei* of Agassiz. Some of the Teleostean fishes, however, are provided with *ganoid* scales.

Excluding the *Leptolepidæ*, which are sometimes referred to this order, the *Teleostei* do not seem to have any representatives in times anterior to the Cretaceous period—that is, towards the close of the Mesozoic period. From this time on, however, Bony Fishes with cycloid or ctenoid scales are the chief fossil representatives of the whole class of the fishes, and the order appears to have attained its maximum at the present day.

The order *Teleostei* is divided into the following sub-orders:

SUB-ORDER A. MALACOPTERI, Owen (= *Physostomata*, Müller).—This sub-order is defined by usually possessing a complete set of fins, supported by rays, all of which are "*soft*" or many-jointed, with the occasional exception of the first rays in the dorsal and pectoral fins. A swim-bladder is always present,

and always communicates with the œsophagus by means of a duct, which is the homologue of the windpipe. The skin is rarely naked, and is mostly furnished with cycloid scales; but in some cases ganoid plates are present.

The more important families comprised in this sub-order are the *Murænidæ* (Eels), the *Clupeidæ* (Herrings), the Pikes (*Esocidæ*), the *Cyprinidæ* (Carp, Chub, Barbel, &c.), and the *Salmonidæ* (Salmon and Trout). Few of these families appeared in rocks older than the Eocene Tertiary. The *Salmonidæ* are only sparsely represented in deposits older than those of the Post-Tertiary epoch. The *Cyprinidæ* and *Esocidæ* are both represented in the fresh-water deposits of the Tertiary period, and the *Murænidæ* appear for the first time in the Eocene. The genus *Osmeroides* (fig. 279) has been referred

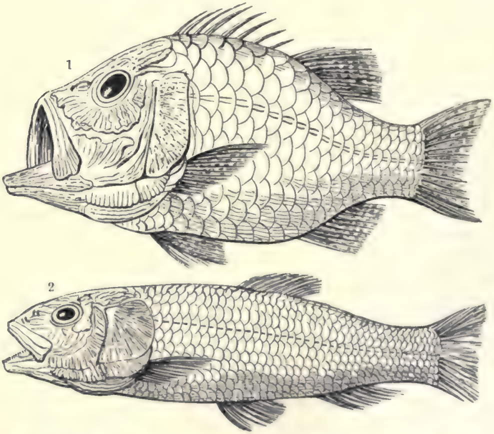


Fig. 279.—1. *Beryx* (*Osmeroides*) *Lewesiensis*, a Percoid fish from the Chalk; 2. *Osmeroides Mantelli*, a Salmonoid fish from the Chalk.

to a position in the neighbourhood of the *Salmonidæ*, and dates from the Cretaceous period. The Clupeoids, also, make their first appearance in the Cretaceous period. Also in this group are the Sheat-fishes (*Siluridæ*), which are chiefly noticeable because they are amongst the small number of living fishes possessed of structures of the same nature as

the fossil spines known as "ichthyodorulites." The structure in question consists of the first ray of the pectoral fins, which is largely developed and constitutes a formidable spine, which the animal can erect and depress at pleasure. Unlike the old "ichthyodorulites," however, the spines of the *Siluridæ* have their bases modified for articulation with another bone, and they are not simply hollow and implanted in the flesh. The "Siluroids" are also remarkable for their resemblance to certain of the extinct Ganoid fishes (*e.g.*, *Pterichthys*, *Coccosteus*, &c.), caused by the fact that the head is protected with an exoskeleton of dermal bones. The Siluroid fishes, however, are hardly represented at all in the fossil state, being only known by two or three doubtful Tertiary examples.

SUB-ORDER B. ANACANTHINI.—This sub-order is distinguished by the fact that the fins are entirely supported by "soft" rays, and never possess "spiny" rays; whilst the ventral fins are either wanting, or, if present, are placed under the throat, beneath or in advance of the pectorals, and supported by the pectoral arch. The swim-bladder may be wanting, but when present it does not communicate with the œsophagus by a duct.

The only important families in this sub-order are the *Gadidæ* (Cod-family) and the *Pleuronectidæ* (Flat Fishes). The *Gadidæ*

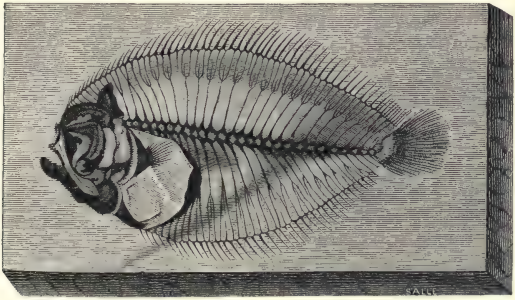


Fig. 280.—*Rhombus minimus.* A small fossil Turbot from the Eocene Tertiary of Monte Bolca.

comprise the living Cod, Haddock, Whiting, &c., and appear to date their existence from the Eocene Tertiary. The *Pleuronectidæ* comprise the living Sole, Flounder, Plaice, and the like, in which the body is very much compressed from side to

side, and is bordered by long dorsal and anal fins. The bones of the head are twisted in such a manner that both eyes are brought to one side of the body. The fish keeps this side uppermost, and is dark-coloured on this aspect; whilst the opposite side, on which it rests, is white. The mouth has the two sides unequal, the pectorals are rarely of the same size, the ventrals look like a continuation of the anal fin, and the branchiostegal rays are six in number. The *Pleuronectidæ* are only known by two or three fossils, of which the oldest is the little *Rhombus minimus* (fig. 280) of the Eocene deposits of Monte Bolca.

SUB-ORDER C. ACANTHOPTERI.—This sub-order is characterised by the fact that one or more of the first rays in the fins are in the form of true, unjointed, inflexible, "spiny" rays. The exoskeleton consists, as a rule, of ctenoid scales. The ventral fins are generally beneath or in advance of the pectorals, and the duct of the swim-bladder is invariably obliterated.

The chief living families of this sub-order are the Perch family (*Percidæ*), the Mullets (*Mugilidæ*), the Mackerel family (*Scomberidæ*), the Gurnards (*Sclerogenidæ*), the Blennies (*Blenniidæ*), the Gobies (*Gobiidæ*), and the Chætodons (*Chætodontidæ*). The fossil representatives of this sub-order are mainly Tertiary; but the genus *Beryx* (fig. 279) dates from the Cretaceous period. In the Eocene Tertiary of Monte Bolca occur several remarkable forms, of which one of the most singular is the Chætodont genus *Platax* (fig. 281).

SUB-ORDER D. PLECTOGNATHI.—This sub-order is characterised by the fact that the maxillary and premaxillary bones are immovably connected on each side of the jaw. The endoskeleton is only partially ossified, and the vertebral column often remains permanently cartilaginous. The exoskeleton is in the form of ganoid plates, scales, or spines. The ventral fins are generally wanting, and the air-bladder is destitute of a duct.

This sub-order includes the living Trunk-fishes (*Ostraciontidæ*), File-fishes (*Balistidæ*), and Globe-fishes (*Gymnodontidæ*). The fossil forms are few in number, and the earliest date from the Eocene Tertiary. They are chiefly noticeable for the resemblance to the true Ganoid fishes, produced by their partially ossified endoskeleton and by their possession of *ganoid* scales.

SUB-ORDER E. LOPHOBRANCHII.—This is a small and unimportant group, mainly characterised by the peculiar structure of the gills, which are arranged in little tufts upon the branchial arches, instead of the comb-like plates of the typical bony

fishes. The endoskeleton is only partially converted into bone, and the exoskeleton, by way of compensation, consists of ganoid plates. The swim-bladder is destitute of an air-duct.

This sub-order comprises the living Pipe-fishes (*Syngnathidæ*) and Sea-horses (*Hippocampidæ*). A few fossil forms are known, dating from the Eocene Tertiary.

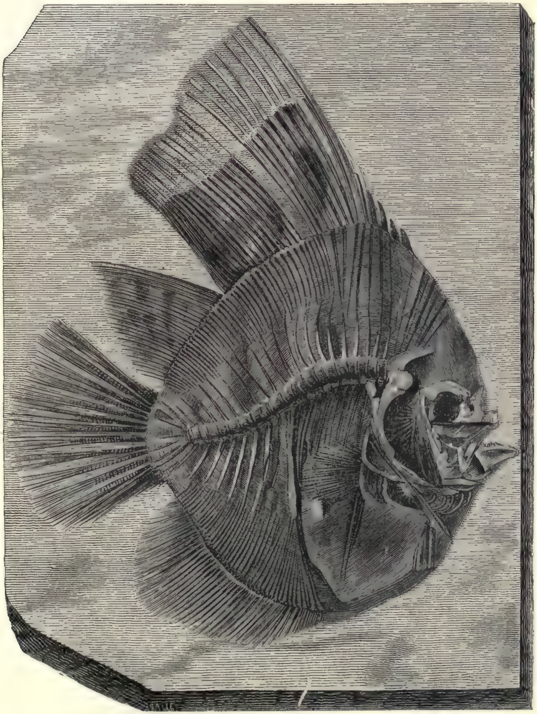


Fig. 281.—*Platax altissimus*, a Chætodont from the Eocene Tertiary of Monte Bolca.

Order II. Ganoidei.—The order of the true Ganoid Fishes may be defined by the following characters.—*The endo-*

skeleton is only partially ossified, the vertebral column mostly remaining cartilaginous throughout life, especially amongst the extinct forms of the Palæozoic period, in which the notochord is persistent. The skull is furnished with distinct cranial bones, and the lower jaw is present. The exoskeleton is in the form of ganoid scales, plates, or spines. There are usually two pairs of limbs, in the form of fins, each supported by fin-rays. The first rays of the fins are mostly in the form of strong spines. The pectoral arch has a clavicle, and the posterior limbs (ventral fins) are placed close to the anus. The caudal fin is mostly unsymmetrical or "heterocercal." The swim-bladder is always present, is often cellular, and is provided with an air-duct. The intestine is often furnished with a spiral valve. The gills and opercular apparatus are essentially the same as in the Bony fishes. The heart has one auricle and a ventricle, and the base of the branchial artery is dilated into a bulbus arteriosus, which is rhythmically contractile, is furnished with a distinct coat of striated muscular fibres, and is provided with several transverse rows of valves.

Of these characters, those which it is most important to remember are the following :—

I. The *endoskeleton* is rarely thoroughly ossified, but varies a good deal as to the extent to which ossification is carried. In some forms, including most of the older members of the order, the chorda dorsalis is persistent, no vertebral centra are developed, and the skull is cartilaginous, and is protected by ganoid plates. Even in these forms, however, the peripheral elements of the vertebræ are ossified. In others, the bodies of the vertebræ are marked out by osseous or semi-cartilaginous rings, enclosing the primitive matter of the notochord. In others, the vertebræ are like those of the Bony fishes—that is to say, deeply biconcave or "amphicœlous." In one Ganoid, however—the Bony Pike (*Lepidosteus*)—the vertebral column consists of a series of "opisthocœlous" vertebræ—that is to say, vertebræ which are convex in front and concave behind. This is the highest point of development reached in the spinal column of any fish, and its structure is more Reptilian than Piscine.

II. The *exoskeleton* consists, in all Ganoid fishes, of scales, plates, or spines, which are said to possess *ganoid* characters. The peculiarities of these scales are that they are composed of two distinct layers—an inferior layer of bone and a superficial covering of a kind of enamel, somewhat similar to the enamel of the teeth, called "ganoine." In form the ganoid scales most generally exhibit themselves as rhomboidal plates, placed edge to edge, without overlapping, in oblique rows, the plates

of each row being often articulated to those of the next by distinct processes. In other cases the ganoid structures are simply in the form of detached plates, tubercles, or spines; and in some cases their *shape* is even undistinguishable from the horny scales of the typical Teleostean fishes. In all cases, however, whatever their form may be, they have the distinctive ganoid structure, being composed of an inferior layer of true bone and a superior layer of enamel. It is to be remembered, however, that these *ganoid* plates and scales are not confined to the fishes of the order *Ganoidei*, but that they occur in two sub-orders of the Bony Fishes—namely, the *Plectognathi* and *Lophobranchii*—and in some others of the *Teleostei* as well.

III. As to the *fins*, both pectorals and ventrals are usually present, and the ventrals are always placed far back, in the neighbourhood of the anus, and are never situated in the immediate vicinity of the pectorals. In some living and many extinct forms the fin-rays of the paired fins are arranged so as to form a fringe round a central lobe (fig. 282). This struc-

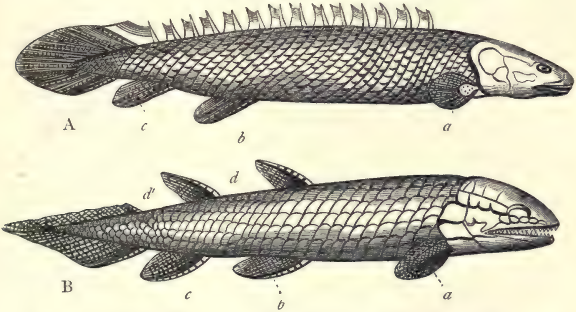


Fig. 282.—Ganoid Fishes. A, *Polypterus* (recent); B, *Osteolepis* (extinct). *a* One of the pectoral fins, showing the fin-rays arranged round a central lobe; *b* One of the ventral fins; *c* Anal fin; *d* Dorsal fin; *d'* Second dorsal fin.

ture characterises a division of Ganoids called by Huxley, for this reason, *Crossopterygidæ*, or "fringe-finned." The form of the caudal fin varies, the Ganoids being in this respect intermediate between the Bony fishes, in which the tail is "homocercal," and the Sharks and Rays, in which there is a "heterocercal" caudal fin. In the majority of Ganoids, then, the tail is unsymmetrical or "heterocercal," but it is sometimes equilobed or "homocercal."

As regards the general *distribution in time* of the *Ganoidei*, the oldest representatives of the fishes belong, so far as is yet known with certainty, to this order. The order, namely, is represented in the Upper Silurian Rocks of Bohemia and Britain by several Ganoid fishes, which have been referred to five distinct genera. In the Devonian Rocks, or Old Red Sandstone, the Ganoids attain their maximum. The singular family of the *Cephalaspidæ* appears to die out finally at the close of this period, and the great group of the *Crossopterygidæ* attained here its highest development, being represented at the present day by the single genus *Polypterus*. The Carboniferous and Permian Rocks contain an abundance of Lepidoganoids. In the Mesozoic period, the Lepidoganoids are very largely represented by various extinct types, many of which belong to the family of the *Lepidosteidæ*—represented at the present day by the Bony Pike or Gar-pike of North America. Here, also, we have for the first time representatives of the family of the *Sturionidæ*, to which the living Sturgeons belong. Lastly, in the Oolitic Rocks appear for the first time Lepidoganoids with homocercal tails, and they continue to be represented up to the present day. In the Tertiary Rocks true Sturgeons (*Acipenser*) make their appearance; but the Ganoids are now considerably outnumbered by the Teleostean fishes; and the latter have a still more marked predominance at the present day.

The *classification* of the Ganoid Fishes has hitherto proved a matter of extreme difficulty; and probably no arrangement that has been as yet proposed can be regarded as being, in all its details, more than provisional. A convenient primary division is that into *Lepidoganoids*, in which the body is furnished with scales of moderate size, and the endoskeleton is generally more or less perfectly ossified; and *Placoganoids*, in which the skeleton is imperfectly ossified, and the head and more or less of the body are protected by large ganoid plates, which in many cases are united together by sutures. Accepting this division, the order *Ganoidei* may be divided into the following sub-orders:—

SECTION 1. LEPIDOGANOIDEI.

Sub-order A. *Amiadæ*.
——— B. *Lepidosteidæ*.
——— C. *Lepidopleuridæ*.
——— D. *Crossopterygidæ*.
——— E. *Acanthodidæ*.

SECTION 2. PLACOGANOIDEI.

Sub-order F. *Ostracostei*.
——— G. *Sturionidæ*.

The position of at least two of these sub-orders (viz., *Acanthodidæ* and *Ostracostei*) in the order of the Ganoids is questionable; whilst the *Sturionidæ* have been referred elsewhere. In any case, the number of forms included in these sub-orders is so large that nothing more can be done here than simply to draw attention to some of the more striking examples of each.

SUB-ORDER A. AMIADÆ.—In this sub-order are included Ganoids in which the scales are rounded and overlap one another, and the tail is homocercal. The vertebral column is ossified, and the external appearance approaches closely to that of an ordinary Teleostean fish. A few fossil forms from the Tertiary Rocks have been more or less doubtfully referred to this group; and the sub-order is represented at the present day by various American fishes, all belonging to the genus *Amia*.

SUB-ORDER B. LEPIDOSTEIDÆ. — Scales rhomboidal, not overlapping; tail heterocercal, sometimes homocercal; paired fins not lobate; fin-borders generally with fulcral scales; true branchiostegal rays. This sub-order is represented at the present day by the Gar-pike (*Lepidosteus*) of the North American continent, and it attained its greatest development in the Mesozoic period. The exact range of the sub-order in time is uncertain, as it has not yet been determined what forms should be included in it. If *Cheirolepis* be excluded, the sub-order is not represented at all in the Devonian Rocks. In the Carboniferous and Permian Rocks the sub-order is mainly represented by the genera *Palæoniscus* and *Amblypterus* (fig. 283), in which the tail is heterocercal, and the jaws are furnished with

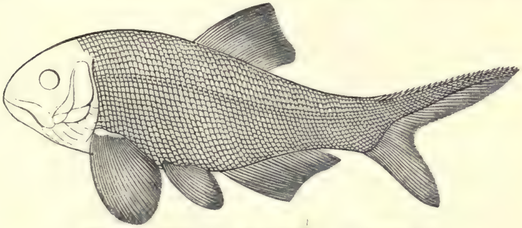


Fig. 283.—*Amblypterus macropterus.* Carboniferous.

numerous minute teeth. Numerous species of these genera are known in the above-mentioned formations, and both appear for the last time in the Trias. In the Secondary Rocks *Lepidosteids* are extremely abundant, the chief forms belonging to the

families *Dapedidæ*, *Lepidotidæ*, and *Leptolepidæ*. In the *Dapedidæ* (fig. 284, 1), the tail-fin is only slightly heterocercal, and the

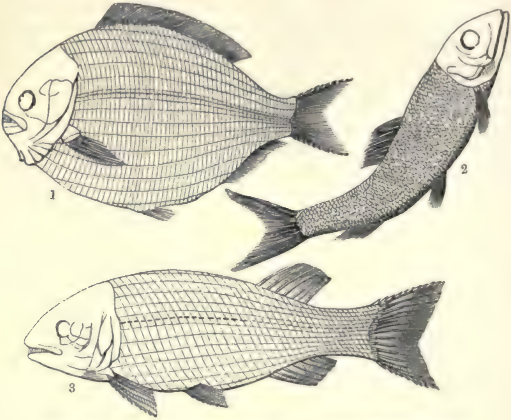


Fig. 284.—1. *Dapedius tetragonolepis.* 2. *Leptolepis sprattiformis.* 3. *Lepidotus Valdensis.*

back teeth are obtuse. *Dapedius* itself is compressed and deep-bodied, and is exclusively confined to the Lias. The front-teeth in this genus are notched or bifurcate. *Æchmodus* is also

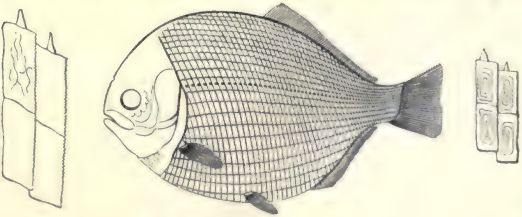


Fig. 285.—*Tetragonolepis* (restored). Lias.

exclusively Liassic; but *Semionotus* and *Pholidophorus* range upwards to the Chalk or to the highest Oolitic strata. The Oolitic genus *Tetragonolepis* (fig. 285) is closely similar to *Da-*

pedius, but the front teeth are not notched. The body is greatly compressed, and there is a single long dorsal fin. The place of this genus is disputed, and it is often referred to the *Pycnodonts*. The *Lepidotidæ* have a homocercal tail (fig. 283, 3), and possess obtuse teeth. The type-genus, *Lepidotus*, ranges from the Lias to the Eocene Tertiary. The *Leptolepidæ* (fig. 283, 2) have also a homocercal tail, and possess small rounded scales. The species of this family are all Secondary in their distribution.

Sub-order C. Lepidopleuridæ.—"Ganoids with heterocercal equilobate tails. Body rhomboidal, covered with rhombic scales, articulated by strong ribs traversing their anterior margins internally. Dorsal fin equal to half the length of the trunk. Anal fin also with an elongate base. Ventrals, when present, small. Paired fins non-lobate. Branchiostegal rays not taking the form of broad plates. Notochord persistent. Arches well ossified."—(Young.) The two most important families of this sub-order are the *Platysomidæ* and *Pycnodontidæ;* of which the former is mainly Carboniferous and Permian, whilst the latter is almost exclusively Mesozoic. In the genus *Platysomus* (fig. 286) the

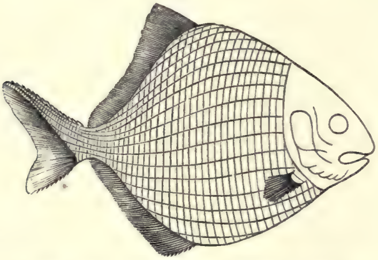


Fig. 286.—*Platysomus gibbosus*. Middle Permian.

tail is heterocercal, the dorsal and anal fins are long, the pectorals are small, and the ventrals appear to be wanting. The teeth are conical and uniserial, and the body is deep and compressed from side to side. The *Platysomi* are mainly found in the Permian Rocks. In the true *Pycnodonts* the teeth are multiserial, and are adapted for crushing; consisting of "a circular or transversely oval crown, flattened above, and sessile on the bone to which it is attached; or of an

obtusely conical crown, which is broader than its peduncle of support" (Young). The Pycnodonts are mainly Oolitic, but a few Cretaceous species are known, and one form has been described from the Eocene Tertiary. The Triassic *Placodus*, formerly referred to this family, is now known to be truly Reptilian.

SUB-ORDER D. CROSSOPTERYGIDÆ.—"Dorsal fins two, or, if single, multifid or very long; the pectoral, and usually the ventral, fins lobate; no branchiostegal rays, but two principal, with sometimes lateral and median, jugular plates, situated between the rami of the mandible; caudal fin diphycercal, or heterocercal; scales cycloid or rhomboid, smooth or sculptured."—(Huxley.)

All the Ganoids of this sub-order are pre-eminently distinguished by the structure of the paired fins, the pectorals always, and the ventrals usually, consisting of a central lobe or stem, which is covered by scales, and to the sides of which the fin-rays are attached. The nearest approach to this structure amongst living fishes is found in the paired fins of the Barramunda (*Ceratodus Fosteri*) of the rivers of Queensland. In this singular fish, which is at present referred to the order of the *Dipnoi*, the pectoral and ventral fins are supported by a median, many-jointed, cartilaginous rod, to which numerous lateral branches are attached. The scales in this sub-order are sometimes rhomboidal, not overlapping one another; at other times they are cycloidal in shape, and are arranged in an imbricate manner.

Professor Huxley divides the *Crossopterygidæ* into the following families. (*See* 'Memoirs of the Geological Survey of Great Britain. Decade X.'):—

Fam. 1.—POLYPTERII.

Dorsal fin very long, multifid; scales rhomboidal.
Polypterus (fig. 282).

Fam. 2.—SAURODIPTERINI.

Dorsal fins two; scales rhomboidal, smooth; fins sub-acutely lobate.
Diplopterus, *Osteolepis* (fig. 282), *Megalichthys*.

Fam. 3.—GLYPTODIPTERINI.

Dorsal fins two; scales rhomboidal or cycloidal, sculptured; pectoral fins acutely lobate; dentition dendrodont.

Sub-fam. A. with rhomboidal scales.
Glyptolæmus (fig. 287), *Glyptopomus*, *Gyroptychius*.

Sub-fam. B. with cycloidal scales.
Holoptychius (fig. 288), *Glyptolepis*, *Platygnathus* [*Rhizodus*, *Dendrodus*, *Cricodus*, *Lamnodus*].

Fam. 4.—CTENODIPTERINI.

Dorsal fins two; scales cycloidal; pectorals and ventrals acutely lobate; dentition ctenodont.
Dipterus [*Ceratodus? Tristichopterus?*]

Fam. 5.—PHANEROPLEURINI.

Dorsal fin single, very long, not subdivided, supported by many interspinous bones; scales thin, cycloidal; teeth conical; ventral fins very long, acutely lobate.
Phaneropleuron (fig. 290).

Fam. 6.—CŒLACANTHINI.

Dorsal fins two, each supported by a single interspinous bone; scales cycloidal; paired fins obtusely lobate; air-bladder ossified. *Cœlacanthus, Undina, Macropoma.*

As regards the distribution of the *Crossopterygidæ* in time, Professor Huxley remarks:—"Of the six families which compose it, four are not only Palæozoic, but are, some exclusively, and all chiefly, confined to rocks of Devonian age—an epoch in which, so far as our present knowledge goes, no fish belonging to the sub-orders of the *Amiadæ* and *Lepidosteidæ* (unless *Cheirolepis* be one of the latter) makes its appearance. Rapidly diminishing in number, the Crossopterygidæ seem to have had several representatives in the Carboniferous epoch; but after this period (unless *Ceratodus* be a *Ctenodipterine*) they are continued through the Mesozoic age only by a thin, though continuous, line of Cœlacanthini, and terminate, at the present day, in the two or three known species of the single genus *Polypterus*."

Of the extinct types of this sub-order, some are sufficiently important to merit especial mention. In the family of the *Saurodipterini*, the genus *Osteolepis* (fig. 282) has a very heterocercal tail and smooth scales. The first dorsal is placed near the centre of the back, and the mouth is furnished with sharp teeth. All the species of this genus are Devonian. The Carboniferous genus *Megalichthys* appears also to belong here. In this singular genus are large "sauroid" fishes with heterocercal tails, rhomboidal scales, and great conical incurved teeth, which are mostly smooth, but are sometimes finely ridged.

Of the *Glyptodipterini* with rhomboidal scales, *Glyptolæmus* (fig. 287) may be taken as the type. In this singular fish, the body is elongated and the head depressed. There are two dorsal fins which are placed very far back, and the ventrals have a similar posterior position. The tail is "divided into two equal lobes by the prolonged conical termination of the body," becoming thus "diphycercal." *Glyptolæmus* is exclusively confined to the Devonian period.

Of the *Glyptodipterines* with cycloidal scales, the most important form is *Holoptychius* (fig. 288). In this genus there are two dorsal fins placed very far back, and the

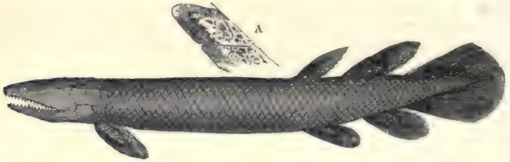


Fig. 287.—*Glyptolæmus Kinnairdi.* Restored. A. Scale of the same. Devonian.

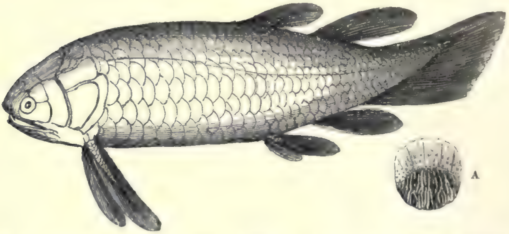


Fig. 288.—*Holoptychius nobilissimus.* Restored. A, Scale of the same. Devonian.

ventrals are similarly approximated to the tail, as in *Glyptolæmus.* The body, however, is covered with large scales of a cycloidal form, which overlap one another, and have wrinkled surfaces; and the tail is inequilobed. The teeth are of two sizes, and the larger ones are longitudinally striated at their bases. The true *Holoptychii* are Devonian in their distribution. In the Carboniferous Rocks, however, occurs the nearly allied genus *Rhizodus* (fig. 289), in which the teeth agree with those of *Holoptychius* in being of two sizes, but they differ in being trenchant on both sides. *Rhizodus* must have attained a large size, and must have been highly predaceous in its habits.

The type-genus of the *Ctenodipterini* is *Dipterus*, in which the position and form of the fins are very much the same as in *Holoptychius.* The body is also covered with cycloidal overlapping scales; but these scales are smooth. The head is protected by a kind of helmet formed of the anchylosed

cranial bones, and the teeth are conical in form and nearly equal in size. The species of *Dipterus* are all Devonian.

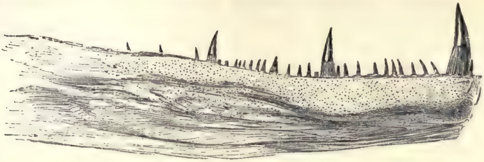


Fig. 289.—Jaw of *Rhizodus Hibberti*. Carboniferous.

The family *Phanopleurini* comprises only the single genus *Phaneropleuron* (fig. 290), which is probably exclusively Devonian. In this singular genus the scales are very thin, cycloidal, and overlapping one another. The dorsal fin is extremely long, and is confluent with the tail-fin, and the pectorals and ventrals are acutely lobate. The jaws are armed with a single series of short conical teeth, and the notochord was persistent.

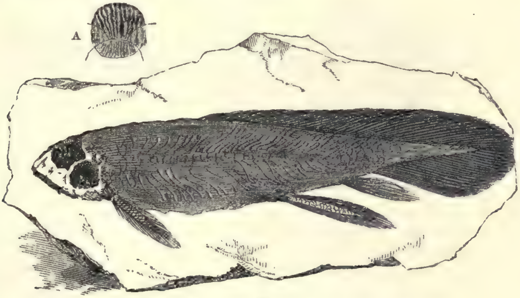


Fig. 290.—*Phaneropleuron Andersoni* and scale. Devonian.

Lastly, the family of the *Cœlacanthi* comprises forms which range from the Devonian to the Cretaceous period, and which are distinguished, in the typical genera, by having hollow fin-spines, by having two dorsal fins, each supported by a single interspinous bone, by having cycloidal overlapping scales, and by the remarkable peculiarity that the swim-bladder was ossified. The type-genus *Cœlacanthus* seems to range from the Carboniferous to the Trias.

SUB-ORDER E. ACANTHODIDÆ.—Scales exceedingly small, shagreen-like; the front of each fin provided with a strong spine, simply implanted in the flesh; no distinctly ossified cranial bones; no operculum; tail heterocercal. In their fin-spines, and in some other points, the *Acanthodidæ* approximate closely to the *Elasmobranchii;* but they are generally regarded as an order of the *Ganoidei.* The *Acanthodidæ* are mainly Devonian, but some forms occur in the Carboniferous Rocks, and a species from the Permian Rocks has been doubtfully referred here. *Acanthodes* (fig. 291) has a single dorsal fin, and

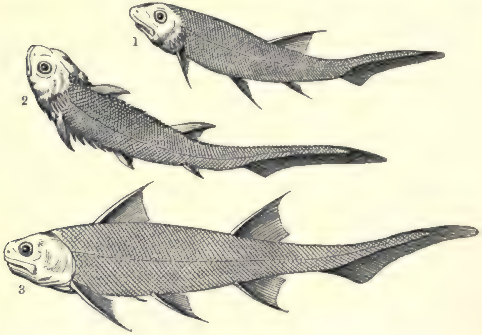


Fig. 291.—1. *Acanthodes Mitchelli.* 2. *Climatius scutiger.* 3. *Diplacanthus gracilis.* Devonian.

is represented in both Devonian and Carboniferous deposits. *Diplacanthus* (fig. 291, 3) has two dorsal fins, and is exclusively confined to the Devonian Rocks.

SUB-ORDER F. OSTRACOSTEI.—The Ganoids of this sub-order are characterised by having the head, and generally the anterior portion of the trunk as well, encased in a strong armour composed of numerous large ganoid plates, immovably united to one another. The posterior extremity of the body is more or less completely unprotected; and whilst the notochord is persistent, the peripheral elements of the vertebræ are ossified. The fishes belonging to this section are the most ancient of their class, commencing in the Upper Silurian Rocks. They extend through the Devonian series, but are not known to have survived into the Carboniferous period.

They have generally been placed amongst the Ganoids; but Professor Huxley has pointed out that they present, many of them, features by which they approximate closely to the Siluroids amongst the Teleosteans. The more important genera included in this sub-order are *Cephalaspis, Pteraspis, Coccosteus,* and *Pterichthys.*

Cephalaspis (fig. 292) is the type of the family of the *Cephalaspidæ,* and is readily recognised by the fact that the cephalic shield has its posterior angles produced into long "cornua,"

Fig. 292.—*Cephalaspis Lyellii.* (After Page.) Old Red Sandstone.

giving it the shape of a "saddler's knife." Besides these lateral cornua, there is a "posterior cornu" or spine, formed by a prolongation backwards of the hinder margin of the shield in the middle line. The orbits are approximated, and are placed nearly in the centre of the cephalic shield. No jaws or teeth are known, and the mouth was probably soft, and adapted for suction. The head-shield exhibits vascular canals, and shows very distinct bone-cells when examined in thin sections under the microscope. The body is covered with ganoid scales, and there is a well-marked dorsal fin. Pectoral fins have also been described, and the tail is clothed with a heterocercal fin. In the nearly allied *Auchenaspis,* the structure is very similar to the above, but there is no spine or "posterior cornu," and there is instead a neck-plate formed by an extension backwards from the cephalic shield. The *Cephalaspidæ* are mainly found in the Old Red Sandstone, the commonest species being *C. Lyellii.* Other species are found in the "passage-beds" between the Silurian and Old Red, and the genus is not wholly unrepresented in the Upper Silurian deposits.

In the genus *Pteraspis* (fig. 293) the head is defended, as in *Cephalaspis,* by a shield or buckler, which is composed of several pieces firmly anchylosed. The shield consists of a central disc, the lateral angles of which are produced into short cornua,

whilst it is extended into a rostrum in front. The posterior spine is very small, and is attached to the disc as a separate piece. The orbits are situated laterally. The minute structure of the shield is very complex, consisting of three layers. The innermost layer is laminated, and is traversed by vascular canals. The middle layer is made up of polygonal cavities; and the outer layer is structureless or fibrous, and is finely striated or grooved. The body was covered with scales; but nothing is known of the nature of the fins. The genera *Cyathaspis* and *Scaphaspis* have been founded upon forms which have usually been placed under *Pteraspis*, and which differ in more or less essential points from the typical species of this genus. The genus *Pteraspis*, so far as yet known, comprises the most ancient of the fishes, commencing as it does in the earlier portion of the Ludlow formation (Upper Silurian). Other species are known in the Old Red Sandstone; but the genus appears to have entirely disappeared before the close of the Devonian period.

Fig. 293. — Cephalic buckler of *Pteraspis* (*Cyathaspis*) *Banksii*. From the Upper Ludlow Rocks of Ludlow. (After Murchison.)

In the genus *Coccosteus* the head was protected by a great shield, the plates of which are covered with small hemispherical tubercles. There is also a ventral or "sternal" shield, which, according to Huxley, seems to have had no direct connection with the cephalic buckler. The mouth was furnished with a distinct lower jaw or "mandible," composed of two rami, carrying small teeth. The notochord was persistent, but the neural and hæmal spines of the vertebræ, and the rays of the dorsal and anal fins, are well ossified. A heterocercal tail-fin was doubtless present as well. The genus *Coccosteus* is essentially Devonian; but a species has been discovered by M. Barrande in the Upper Silurian of Bohemia.

In the genus *Pterichthys* (fig. 294) are some very remarkable fishes, first discovered in the Old Red Sandstone by the late Hugh Miller, and nearly related in most respects to *Coccosteus*. The whole of the head and the anterior part of the trunk were defended by a buckler of large ganoid plates suturally united, those covering the trunk forming a back-plate and a breast-plate articulated together at the sides. The rest of the body was covered with small ganoid scales. A small dorsal fin, a pair of ventrals, a pair of pectorals, and a heterocercal tail-fin were present. The form of the pectoral fins is the peculiar

characteristic of the genus. These were in the form of two long curved spines, somewhat like wings, covered by finely-tuberculated ganoid plates. From their form they cannot have been of much use in swimming; but they probably, as suggested by Owen, enabled the animal to shuffle along the sandy bottom of the sea, if stranded at low water. All the species of *Pterichthys* are exclusively confined to the Old Red Sandstone.

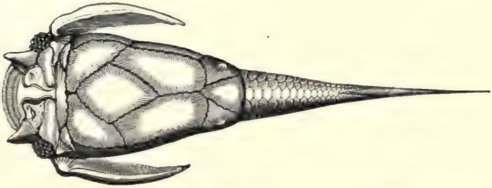


Fig. 294.—*Pterichthys cornutus.* Old Red Sandstone.

SUB-ORDER G. STURIONIDÆ.—In this sub-order the skeleton is almost altogether cartilaginous, and the notochord is persistent. The exoskeleton is usually in the form of large ganoid plates, which are united into a shield over the head, but are detached over the body. Sometimes the exoskeleton is almost absent, and in no case is the mouth furnished with teeth. The tail is heterocercal.

This sub-order comprises the living Sturgeons, and is not known with certainty to have come into existence before the Eocene Tertiary, where it is represented by the *Acipenser toliapicus* of the London Clay. In the Lias, however, occur two species of the singular genus *Chondrosteus*, which have usually been referred here, and have been regarded as being most nearly allied to the Paddle-fishes (*Spatularia*) of North America. The skull, however, is more completely ossified than is the case with any living members of the *Sturionidæ;* and the true place of *Chondrosteus* must be regarded as uncertain.

CHAPTER XXX.

ORDERS OF FISHES—Continued.

ORDER III. ELASMOBRANCHII (= *Selachia*, Müller; *Placoidei*, Agassiz; *Holocephali* and *Plagiostomi*, Owen).—This order includes the Sharks, Rays, and Chimæræ, and corresponds with the greater and most typical portion of the *Chondropterygidæ* or Cartilaginous Fishes of Cuvier. The order is distinguished by the following characters:—*The skull and lower jaw are well developed, but there are no cranial bones, and the skull consists of a single cartilaginous box, without any indication of sutures. The vertebral column is sometimes composed of distinct vertebræ, sometimes cartilaginous or sub-notochordal. The exoskeleton is in the form of placoid granules, tubercles, or spines. There are two pairs of fins, representing the limbs, and supported by cartilaginous fin-rays; and the ventral fins are placed far back near the anus. The pectoral arch has no clavicle. The heart consists of a single auricle and ventricle, and the bulbus arteriosus is rhythmically contractile, is provided with a special coat of striated muscular fibres, and is furnished with several transverse rows of valves. The gills are pouch-like.*

In most of the above characters it will be seen at once that the *Elasmobranchii* agree with the Ganoid fishes, especially as regards the structure of the heart. The following points of difference, however, require more special notice:—

I. The *exoskeleton* is what is called by Agassiz "placoid." It consists, namely, of no continuous covering of scales or ganoid plates, but of more or less numerous detached grains, tubercles, or spines, composed of bony matter, and scattered here and there in the integument. In the case of the Rays, these placoid ossifications often take a very singular shape, consisting of an osseous or cartilaginous disc, from the upper surface of which springs a sharp recurved spine, composed of dentine.

II. The *gills* are fixed and pouch-like, and differ very materially from those of the Bony and Ganoid fishes. In the case of the Sharks and Rays, the gill-pouches open upon the surface by a series of separate apertures, which are placed on the sides of the neck in the former, and on the under surface of the body in the latter. In neither is there any gill-cover or operculum, nor are there any branchiostegal rays. In one section of the order, however—viz., the *Holocephali*—though the internal structure of the gills is essentially the same as in

the Sharks, there is only a single branchial aperture or gill-slit externally, and this is protected by a rudimentary operculum and branchiostegal rays.

The order *Elasmobranchii* is divided into the two sub-orders of the *Holocephali* and *Plagiostomi*. The former comprises the living *Chimæræ*, characterised by the mouth being terminal, and there being only a single gill-slit. The latter comprises the living Port Jackson Shark, the true Sharks and Dog-fishes, and the Rays, characterised by having the mouth transverse and placed on the under surface of the head, whilst there are several apertures to the gills.

As regards their *general distribution in time*, the *Elasmobranchii* are nearly as ancient as the Ganoids. At the top of the Upper Ludlow Rocks, or at the close of the Upper Silurian epoch, there have been discovered the remains of undoubted Plagiostomous fishes, most nearly allied to the existing Port Jackson Shark (*Cestracion Philippi*). These remains consist chiefly of defensive spines, which formed the first rays in the dorsal fins, and upon these the genus *Onchus* (fig. 295) has been founded. Besides these there have been found portions of skin or "shagreen," with little placoid tubercles, like the skin of a living shark. These have been referred to the genera *Sphagodus* and *Thelodus*. They are the earliest known remains of Plagiostomous fishes, and with the exception of the few remains from the Lower Ludlow Rocks, they are the earliest known remains of fishes in the stratified series. The discovery of these remains, at that time the earliest known traces of Vertebrate life, is due to the genius of Sir Roderick Murchison, the author of 'Siluria.'

Most of the fossil *Elasmobranchii* belong to the division *Cestraphori* of Owen, so called because they are provided with the large fin-spines which are known to geologists as "ichthyodorulites." The two families of this division—the Cestracionts and Hybodonts—are largely represented in past time, the former chiefly in the Palæozoic period, the latter chiefly in the Mesozoic Rocks. Subjoined is an illustration of the "ichthyodorulites" and teeth of some of the Palæozoic *Cestraphori*.

The true Sharks are represented in the Mesozoic deposits (*e.g.*, by teeth of *Notidanus* in the Oolites); but they are chiefly Cretaceous and Tertiary. The teeth of *Odontaspis*, *Galeocerdo*, and *Carcharodon*, are good examples from the Eocene of the Isle of Sheppey. The true Rays are older than the true Sharks, the Carboniferous fossil *Pleuracanthus* being probably the spine of a Ray (fig. 296). Numerous remains of Rays, chiefly in the form of the pavement-like teeth, are known,

both from the Secondary and Tertiary Rocks. The last division of the *Elasmobranchii*—viz., that of the *Holocephali*—is poorly represented in past time by the Mesozoic and Kainozoic *Ischiodus*, *Elasmodus*, *Ganodus*, and *Edaphodus*.

In the following a more detailed account is given of the characters of the various groups of the *Elasmobranchii*, with the leading characters and more important fossil forms of each :—

SUB-ORDER A. HOLOCEPHALI.—This sub-order includes certain curious fishes, of which the only living forms are the *Chimæridæ*. The notochord is persistent, but the neural arches and transverse processes are cartilaginous. The jaws are bony, and are covered by broad plates representing the teeth. The exoskeleton consists of placoid granules. The first ray of the anterior dorsal fin is in the form of a powerful defensive spine, like the "ichthyodorulites" of many fossil fishes. The ventral fins are abdominal, and the tail is heterocercal. There is only a single external gill-aperture, covered with a gill-cover and branchiostegal membrane; but only a small portion of the borders of the branchial laminæ is free. The mouth is placed at the extremity of the head.

The Chimæroid fishes are not known to have existed at all during the Palæozoic period; but they are not uncommon in the Secondary period and in the Tertiaries. They are exclusively known by means of their jaws and teeth and their fin-spines or "ichthyodorulites." The dental plates are united to the beak-shaped jaws; and the dorsal fin-spines are always movable and jointed—instead of being supported on a cartilage imbedded in the muscular tissue of the back (as in the *Spinacidæ* and *Cestraciontidæ*). Of the fossil Chimæroids, the genera *Ischiodus* and *Ganodus* are exclusively Mesozoic; *Edaphodus* ranges from the Cretaceous series to the Eocene Tertiary; and *Elasmodus* is only known from the Eocene.

SUB-ORDER B. PLAGIOSTOMI.—This sub-order is of considerably greater importance, as it includes the well-known Sharks and Rays. The vertebral centra are usually more or less ossified, and even when quite cartilaginous, the centra are marked out by distinct rings. The skull is in the form of a cartilaginous capsule, without distinct cranial bones. The mouth is transverse, and is placed on the under surface of the head. The exoskeleton consists of placoid granules, tubercles, or spines. The branchial sacs open externally by as many distinct apertures as there are sacs, and there is no operculum. A pair of tubes proceed from the pharynx to open on the upper surface of the head by two apertures, which are termed

"spiracles." By means of these water can be admitted to the pharynx, and thence to the gills.

By Professor Owen the *Plagiostomi* are divided into three sections, termed respectively the *Cestraphori*, the *Selachii*, and the *Batides*.

a. Cestraphori.—In this division there is a strong spine in front of each dorsal fin, and the back teeth are obtuse. The only living representative of this group is the Port Jackson Shark (*Cestracion Philippi*), characterised by its pavement of plate-like crushing teeth, adapted for comminuting small Molluscs and Crustaceans. It is exclusively an inhabitant of the Australian and Chinese seas, and is remarkable for its close resemblance to a large group of extinct forms, of which the best known are the genera *Hybodus* and *Acrodus* from the Secondary Rocks.

The *Cestraphori* are known in a fossil state mainly by their fin-spines, or "ichthyodorulites," and their teeth. It is obvious, however, that it must be often very difficult or altogether impossible to determine absolutely whether a spine or a piece of shagreen belongs to a Cestraciont or to a true Shark. Some of the forms, therefore, to be immediately mentioned, must be regarded as being only provisionally placed amongst the *Cestraciontidæ*.

With this proviso, the earliest known traces of Cestraciont fishes appear to be in the Upper Ludlow Rocks, at the summit of the Silurian series. Here, within the limits of a single stratum, well known as the "bone-bed," occur remains which have been with more or less probability referred to Cestracionts. Some of these (fig. 295) are in the form of compressed,

Fig. 295.—A, Spine of *Onchus tenuistriatus*. B, Shagreen-scales of *Thelodus*. Both from the bone-bed of the Upper Ludlow Rocks.

slightly curved spines, the sides of which are grooved longitudinally. These have been referred to a provisional genus, under the name of *Onchus*, and there appears to be little doubt as to their truly belonging to fishes of some kind. It is, however, quite possible that they really belong to *Pteraspis*, in which case they must be removed from their present place.

Along with the spines of *Onchus* are found fragments of prickly skin or shagreen, which have been referred to the temporary genus *Sphagodus*, along with minute cushion-shaped bodies, which are doubtless placoid scales, and which have

been referred to another genus under the name of *Thelodus* (fig. 295, B). In the same bed are found jaw-like bodies, with tooth-like processes of different sizes, which have been named *Plectrodus*, and have been supposed to be the jaws of fishes. The true nature of these, however, is doubtful, and they certainly do not belong to Plagiostomous fishes. Possibly they are the prickly margins of the cephalic bucklers of Cephalaspidean fishes.

It should be mentioned, also, that M. Barrande enumerates *Ctenacanthus* amongst the fishes found in the Upper Silurian rocks of Bohemia, this genus being otherwise only known in the Devonian and Carboniferous formations.

In the Devonian Rocks the remains of *Cestraphori* are not uncommon. The more important fossil spines of the deposits of this period have been referred to the genera *Onchus*, *Ctenacanthus*, *Homacanthus*, and *Cosmacanthus*. The fossil teeth belong chiefly to the genera *Ctenodus*, *Ctenoptychius*, *Cladodus*, and *Conchodus*.

In the Carboniferous period the remains of *Cestraphori* are comparatively very abundant, though confined generally to

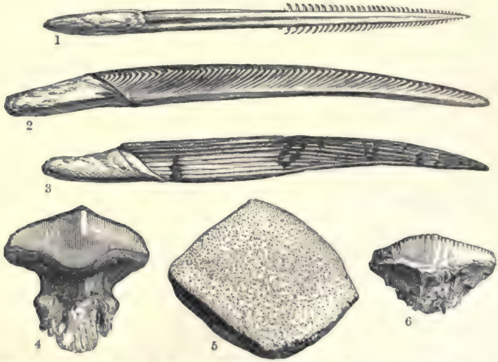


Fig. 296.—1. Fin-spine of *Pleuracanthus* (one of the Rays); 2. *Gyracanthus;* 3. *Ctenacanthus;* 4. Tooth of *Petalodus;* 5. *Psammodus;* 6. *Ctenoptychius*. All from the Carboniferous Rocks.

particular localities. The spines of the Carboniferous strata have been referred to many genera, of which the most important are *Ctenacanthus* (fig. 296, 3), *Gyracanthus* (fig. 296, 2), *Ho-*

macanthus, *Oracanthus*, *Onchus*, *Leptacanthus*, and *Edestes*. The fossil teeth of the Carboniferous Rocks have also been referred to many genera, of which the more important are *Cochliodus* (fig. 297), *Psammodus*, *Orodus*, *Petalodus* (fig. 296, 4), *Ctenoptychius* (fig. 296, 6), *Cladodus*, *Centrodus*, *Glossodus*, and *Petrodus*. Two types may be distinguished in these teeth. In one type, as in *Cochliodus* (fig. 297) or *Psammodus*, the teeth have the form of broad crushing plates, adapted for the comminution of Molluscs or Crustaceans. In fact, in these forms the teeth very closely resemble those of the living Port Jackson Shark (*Cestracion*). In the other type, as in *Cladodus*, *Orodus*, and *Glossodus*, the teeth are of what is called the "Hybodont" form, having a general conical shape, and consisting of a central principal cone, flanked by smaller secondary cones.

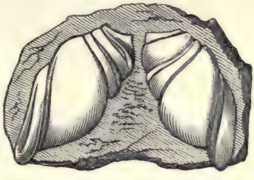


Fig. 297.—Dental plates of *Cochliodus contortus*. Mountain Limestone (Carboniferous).

In the Permian series the remains of *Cestraphori* are scanty, but they are very numerous in all the great formations of the Secondary period. The four most important Mesozoic genera are *Hybodus*, *Acrodus*, *Strophodus*, and *Ptychodus*. The almost exclusively Triassic genus *Ceratodus* has generally been referred here also, but its true affinities are with the *Dipnoi*.

In the genus *Hybodus* (fig. 298) the teeth are shark-like, but are not so trenchant as they are in the true Sharks. They

Fig. 298.—Tooth of *Hybodus*.

Fig. 299.—Fin-spine of *Hybodus*. Cretaceous.

consist of a central "principal" cone, with smaller "secondary" cones on each side. The fin-spines (fig. 299) in this genus are longitudinally grooved, and carry a series of small teeth on their hinder or concave margin. Species of *Hybodus* abound in the Triassic and Jurassic formations, and occur, though less abundantly, in the Cretaceous Rocks.

In the genus *Acrodus* (fig. 300) the teeth are more like those of the Port Jackson Shark. The front teeth are pointed, and

resemble those of the Hybodonts, but the back teeth are adapted for crushing shell-fish. Each of these crushing teeth has an elongated form, with a rounded surface, which is covered with fine transverse striæ proceeding from a central longitudinal line. From their general form, colour, and striation, they are commonly called "fossil leeches" by the quarrymen. As in the case of *Hybodus*, the species of *Acrodus* are exclusively Mesozoic, ranging from the Trias to the Chalk.

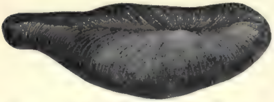


Fig. 300.—Tooth of *Acrodus nobilis*. Lias.

The teeth of *Strophodus* are elongated, very similar to those of *Acrodus* in their general form, but truncated at both ends, and having their surface reticulated. Like the preceding, the species of *Strophodus* range from the Trias to the Chalk.

In the genus *Ptychodus*, lastly, the teeth are more or less quadrate in form, and the summit of the crown of the tooth is thrown into parallel transverse folds, ridges, or plications, surrounded by a granulated area. All the species of this genus are Cretaceous.

A few Tertiary forms of the *Cestraphori* have been described; but the affinities of most of these are doubtful. At the present day the family is represented by the single living species, the Port Jackson Shark (*Cestracion Philippi*).

b. Selachii.—This group comprises the Dog-fishes and Sharks, characterised by the elongated, not rhomboidal, form of the body, and by the lateral position of the gill-slits on the sides of the neck. The teeth are sharp and conical, and are arranged in several rows, of which the outermost alone is employed, the inner ones serving to replace the former when worn out.

This family attains its maximum at the present day, and its earliest authentic representatives appear in the Jurassic period. Some Palæozoic fossils, however, have been, with more or less probability, referred to Sharks, or placed in the neighbourhood of the living Monk-fishes (*Squatina*). With the exception of occasional vertebræ, all the known remains of *Selachians* consist of teeth.

In the Jurassic series are found teeth of *Notidanus* and *Sphenodus*. In the Cretaceous Rocks are numerous teeth, referred to the genera *Corax*, *Galeocerdo*, *Otodus*, *Lamna*, *Oxyrhina*, and *Odontaspis*, all of which continue to be represented in the Tertiary deposits. The teeth of *Carcharodon* (fig. 303) also occur in the Cretaceous series, but the genus is mainly Tertiary. The teeth of *Carcharodon* are triangular,

serrated on both sides, and sometimes of immense size (five or six inches in length). In *Otodus* (fig. 302) the teeth are not denticulated at their edges, and they have a secondary tooth

Fig. 301.—*Oxyrhina xiphodon.* Miocene.

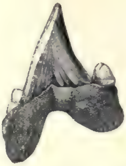


Fig. 302.—*Otodus obliquus.* Eocene.

Fig. 303.—*Carcharodon productus.* Miocene.

at each side of the base. The teeth of *Oxyrhina* (fig. 301), lastly, are large and compressed, differing from those of *Otodus* chiefly in wanting the lateral projections at the base. Upon the whole, the deposits which have yielded the greatest abundance of the teeth of these extinct Sharks, are the Upper Greensand (Cretaceous) and the London Clay (Eocene Tertiary).

c. Batides.—This group includes the Rays and Skates, and is distinguished by the fact that the branchial apertures are placed on the under surface of the body, forming two rows of openings a little behind the mouth. In the typical members of the group, the body is flattened out so as to form a kind of disc (fig. 304), the greater part of which is made up of the enormously developed pectoral fins. Upon the upper surface of the disc are the eyes and spiracles; upon the lower surface are the nostrils, mouth, and branchial apertures. The flattened bodies of the Rays, however, must be carefully distinguished from those of the Flat-fishes (*Pleuronectidæ*). In

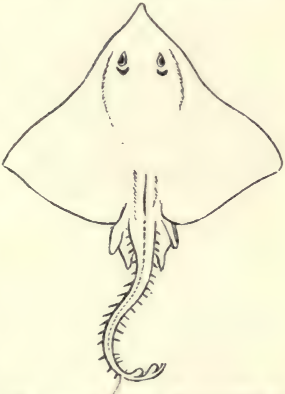


Fig. 304.—Batides. *Raia marginata*, one of the Skates. Reduced one-sixth. (After Gosse.)

the former, the flat surfaces of the body are truly the dorsal and ventral surfaces. In the latter, as before remarked, the body is flattened, not from above downwards, but from side to side, and the head is so twisted that both eyes are brought to one side of the body.

The tail in the Rays is long and slender, usually armed with spines, and generally with two or three fins (the homologues of the dorsal fins). The mouth is paved with flat teeth of a more or less rhomboidal shape. The integument is often furnished with placoid structures of a peculiar shape, consisting of oval or rounded osseous discs, from the centre of each of which springs a curved spine of dentine. The tail also is sometimes armed with a doubly-serrated defensive spine.

The Rays are known in the fossil condition by their flat crushing teeth mainly, but also by their fin-rays, bony discs, and defensive spines. The earliest trace of the Rays is found in the Carboniferous Rocks, where occurs the doubly-serrated spine which is referred to the genus *Pleuracanthus* (fig. 296, 1). In this singular form, however, the spine seems to have been inserted at the back of the head, instead of in the tail, as in the living Sting-rays. In the Jurassic Rocks occur the remains of Rays, which have been referred to the genera *Squaloraia*, *Spathobatis*, *Arthropterus*, &c. In the Tertiary Rocks the remains of Rays are tolerably abundant, and consist almost exclusively of the dental plates. These consist (fig. 305) of generally flat plates, usually somewhat rhomboidal in shape, often placed close together and sometimes united laterally by sutures, so as to "form a kind of mosaic pavement on both the upper and lower jaws" (Owen). Most of the fossil forms belong to the genus *Myliobatis*, which comprises the living Eagle-rays. All the fossil species of this family belong to the Tertiary period.

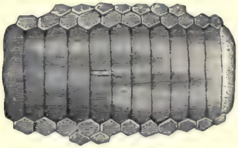


Fig. 305.—Teeth of a fossil Ray (*Myliobatis Edwardsii*). Eocene.

Order IV.—Dipnoi (= *Protopteri*, Owen).—This order is a very small one, and includes only the singular Mud-fishes (*Lepidosiren* and *Ceratodus*); but it is nevertheless of great importance as exhibiting a distinct transition between the Fishes and the *Amphibia*. So many, in fact, and so striking, are the points of resemblance between the two, that until recently the *Lepidosiren* (fig. 306) was always made to constitute the lowest class of the *Amphibia*. The highest authorities, however, now

concur in placing it amongst the fishes, of which it constitutes the highest order. The order *Dipnoi* is defined by the following characters:—*The body is fish-like in shape. There is a skull with distinct cranial bones and a lower jaw, but the notochord is persistent, and there are no vertebral centra, nor an occipital condyle. The exoskeleton consists of horny, overlapping scales, having the "cycloid" character. The pectoral and ventral limbs are both present, but have (in Lepidosiren) the form of awl-shaped, filiform, many-jointed organs, of which the former only have a membranous fringe inferiorly. The ventral limbs are attached close to the anus, and the pectoral arch has a clavicle; but the scapular arch is attached to the occiput. The hinder extremity of the body is fringed by a vertical median fin. The heart has two auricles and one ventricle. The respiratory organs are twofold, consisting on the one hand of free filamentous gills contained in a branchial chamber, which opens externally by a single vertical gill-slit; and on the other hand of true lungs in the form of a double cellular air-bladder, communicating with the œsophagus by means of an air-duct or trachea. The branchiæ are supported upon branchial arches, but these are not connected with the hyoid bone; and in some cases, at any rate, rudimentary external branchiæ exist as well. The nasal sacs open posteriorly into the throat.*

Fig. 306.—Dipnoi. *Lepidosiren annectens.*

Until lately the only known members of the order *Dipnoi* were the *Lepidosiren paradoxa* of South America and the *Lepidosiren* (*Protopterus*) *annectens* of Africa. No fossil also could be referred with any certainty to this order. Recently, however, there has been discovered a most remarkable fish in the rivers of Queensland (Australia), which is almost certainly referable to this order, and which throws great light upon several fossil forms. The organisation of this fish is so extraordinary, and its affinities with some of the extinct Ganoids are so numerous and important, that it will be well to quote at some length the description of it given by Dr. Albert Günther, one of the most eminent of living ichthyologists. The fish in question has been named the *Ceratodus Fosteri*, and it is known locally as the "Barramunda." It is said to attain a length of about six

feet, but its average length is about three feet. The Barramunda "is eel-shaped, but considerably shorter and thicker than a common eel, and covered with very large scales. The head is flattened and broad, the eye lateral and rather small, the mouth in front of the broad snout and moderately wide. The gill openings are a rather narrow slit on each side of the head. There are no external nostrils. The tail, which is of about the same length as the body without the head, is compressed, and tapers to a point, but it is surrounded by a very broad fringe, supported by innumerable fine and long fin-rays. There are two fore and two hind paddles, similar to each other in shape and size, and very different from the fins of ordinary fishes; their central portion being covered with a scaly skin, and the entire paddle surrounded by a rayed fringe. If we were to cut off the hind part of the tail of a fish, the piece would bear a strong resemblance to one of the paired paddles. The vent is situated in the median line of the abdomen between the paddles.

"In order to obtain a view of the inside of the mouth, it is necessary to slit it open, at least on one side. We then notice that there are a pair of nasal openings within and on each side of the cavity of the mouth. The palate is armed with a pair of large, long, dental plates, with a flattish undulated and punctated surface, and with five or six sharp prongs on the outer side, entirely similar to the fossil teeth described under the name of *Ceratodus*. Two similar dental plates of the lower jaw correspond to the upper, their undulated surface fitting exactly to that of the opposite teeth. Beside these molars, the front part of the upper jaw (vomer) is armed with two obliquely placed incisor-like dental lamellæ, which have no corresponding teeth in the lower jaw. As we know the kind of food taken by the Barramunda, the use of these teeth is apparent. The incisors will assist in taking up or even tearing off leaves, which are then partially crushed between the undulated surfaces of the molars.

"The skeleton consists of a cartilaginous basis, in the form of a long tapering chord for the body and tail, and in that of a capsule for the head. No segmentation into separate vertebræ is visible in any part of the notochord; but it supports a considerable number of apophyses, the abdominal of which bear well-developed ribs, all being solid cartilaginous rods, with a thin sheath of bone. In the same manner no part of the brain-capsule is ossified, but it is nearly entirely enclosed in thin bony lamellæ. This is also the structure of the appendages of the skull, as the mandible and the hyoid and scapulary arches.

From a study of the skull, it becomes apparent at once why in fossil teeth of *Ceratodus* nothing or very little of the bone attached to them has been preserved. These teeth rest on cartilage as well as on bone, the latter being a very thin and porous layer which could not be preserved, unless the progress of stratification had been going on with as little disturbance as in the Solenhofen Schiefer; but the matrix in which fossil Ceratodont teeth are found shows that it was formed under very different conditions, and it is certainly not of a nature to permit the supposition that thin porous lamellæ of bone would have been preserved entire.

"The structure of the skeleton reminds us much of that of the sturgeons, Chimæra, and especially of *Lepidosiren;* and of all the modifications by which it differs from these types, perhaps none is of greater interest than that observed in the paddles. The central part of the paddle, which we have found externally to be covered with scales, is supported by a jointed axis of cartilage extending from the root to the extremity of the paddle; each joint bears a pair of three- or two- or one-jointed branches. This is the case in the hind as well as fore paddles, and we are justified in supposing that those extinct Ganoids of which impressions of paddles with scaly centres have been preserved, were provided with a similar internal skeleton."

Upon the whole, Dr. Günther concludes:—1. That the Barramunda is not generically separable from the almost exclusively Triassic genus *Ceratodus,* which was founded simply upon detached teeth; 2. That the Barramunda is very closely allied to certain of the Crossopterygious Ganoids, such as the *Dipterus* of the Old Red Sandstone, the chief difference being, that the tail of the latter is heterocercal; 3. That the order *Dipnoi* should be considered merely as forming a sub-order of the *Ganoidei;* 4. That the *Ganoidei* may be united with the *Elasmobranchii* into a single group, which may be termed *Palæichthyes*, and which is characterised by having a "heart with a contractile bulbus arteriosus, intestine with a spiral valve, and optic nerves non-decussating;" 5. That the *Ganoidei* are the *Fresh-water Palæichthyes,* and the *Elasmobranchii* are the *Marine Palæichthyes.*

If the views of this high authority be ultimately adopted, it will have to be admitted that the *Dipnoi,* instead of being unknown in a fossil state, have enjoyed a vast antiquity, dating their existence from the Lower Old Red Sandstone.

CHAPTER XXXI.

AMPHIBIA.

The class *Amphibia* comprises the Frogs and Toads, the Salamandroids, the *Cæciliæ*, and the extinct *Labyrinthodonts*, and may be briefly defined as follows :—As is the case with the Fishes, *branchiæ, or filaments adapted for breathing air dissolved in water, are always developed upon the visceral arches for a longer or shorter time. On the other hand, the Amphibians differ from the Fishes in the fact that true lungs are always present in the adult; the limbs are never converted into fins; and when median fins are present, as is sometimes the case, these are never furnished with fin-rays. The limbs, when present, exhibit in their skeleton the same parts as do the limbs of the higher Vertebrates. The skull always articulates with the vertebral column by means of two occipital condyles. The heart consists of two auricles and a single ventricle. The nasal sacs communicate posteriorly with the pharynx; and the rectum, ureters, and ducts of the reproductive organs open into a common chamber or "cloaca."*

The great and distinguishing character of the *Amphibia* is the fact that they undergo a *metamorphosis* after their exclusion from the egg. They commence life as water-breathing larvæ, provided with gills or branchiæ; but in their adult state they invariably possess lungs; the branchiæ in the higher forms disappearing when the lungs are developed, but being in other cases permanently retained throughout life.

In the earliest embryonic condition the branchiæ are *external*, placed on the side of the neck, and not situated in an internal chamber as in Fishes. In some cases the external branchiæ only are present, and they are, in any case, the gills which are retained in those forms in which the branchiæ are permanent (*Perennibranchiata*). In the tailed Amphibians (*Urodela*) and in the Frogs and Toads (*Anoura*) two sets of gills are developed—an external set, which is very soon lost, and an internal set, which is retained for a longer or shorter period. As maturity is approached, true lungs adapted for breathing air are developed. The development, however, of the lungs varies with the completeness with which aerial respiration has to be accomplished; being highest in those forms which lose their gills when grown up (*Caducibranchiata*), and lowest in those in which the branchiæ are retained throughout life (*Perennibranchiata*).

The class *Amphibia* is divided into the four orders of the

Ophiomorpha, *Urodela*, *Anoura*, and *Labyrinthodontia*. The first of these includes only the serpentiform animals known as *Cæciliæ*, and not having any certain fossil representatives, may be altogether passed over here. The order *Urodela* comprises the so-called "tailed" Amphibians of the present day, such as the Newts and Salamanders. The earliest traces of this order in past time occur in the Tertiary deposits. The order *Anoura* includes the so-called "tail-less" Amphibians, such as the Frogs and Toads, and is likewise not known to have existed in periods anterior to the Tertiary. Lastly, the order *Labyrinthodontia* is entirely extinct, and is known to have existed only during the Carboniferous, Permian, and Triassic periods.

ORDER I. URODELA (= *Ichthyomorpha*, Owen; *Saurobatrachia*).—This order is commonly spoken of collectively as that of the "Tailed" Amphibians, from the fact that the larval tail is always retained in the adult. The *Urodela* are characterised by having the skin naked, and almost invariably destitute of any exoskeleton. The body is elongated posteriorly to form a compressed or cylindrical tail, which is permanently retained throughout life. The dorsal vertebræ are biconcave (*amphicœlous*), or concave behind and convex in front (*opisthocœlous*), and they have short ribs attached to the transverse processes. The bones of the fore-arm (*radius* and *ulna*) on the one hand, and those of the shank (*tibia* and *fibula*) on the other, are not anchylosed to form single bones.

The best known of the existing *Urodela* are the Newts (*Triton*), the Salamanders (*Salamandra*), the Mud-eels (*Siren*), the Axolotl (*Siredon*), and the Giant-Salamanders (*Menopoma*). Some of these are "perennibranchiate," retaining the branchiæ throughout life; others lose the branchiæ, becoming thus "caducibranchiate," but retain the branchial apertures behind the head; others, lastly, lose both the branchiæ and the branchial apertures. Most of the *Urodela* have the four limbs well developed, but some possess only the anterior limbs.

The geological history of the *Urodela* is short and of little importance. No trace of the order has hitherto been discovered in any deposits older than the Tertiary. The only exception to this statement is constituted by the fossil described from the Lower Permian Rocks by Geinitz under the name of *Palæosiren*, and regarded by him as being most nearly allied to the *Siren lacertina*. It is probable, however, that *Palæosiren* is really referable to the *Labyrinthodontia*. In strata of Tertiary age have been discovered the remains of Newts and Salamanders. The most remarkable fossil referable to this order is the *Andrias Scheuchzeri* (fig. 307) of the Miocene beds of

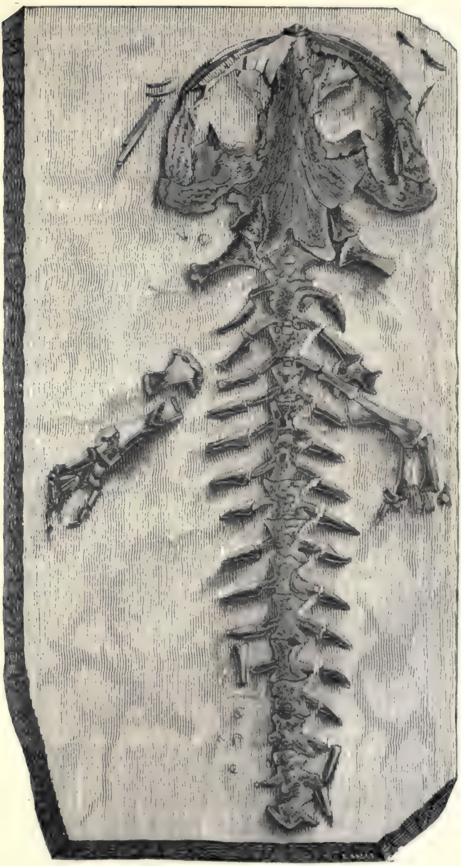


Fig. 307.—*Andrias Scheuchzeri.* Miocene Tertiary.

Oeningen. This singular fossil was described by its original discoverer as human, under the name of *Homo diluvii testis;* but it is really the skeleton of a Salamandroid of large size. It is very closely allied to the Giant Salamander (*Menopoma*, or *Sieboldia, maxima*) of Java.

ORDER II. ANOURA (= *Batrachia*, Huxley; *Theriomorpha*, Owen; *Chelonobatrachia*, &c.)—This order includes the Frogs and Toads, and is perhaps best designated by the name of *Anoura*, or "Tail-less" Amphibians. The name *Batrachia*, employed by Huxley, is inexpedient, partly because it is used by Owen to designate the entire class *Amphibia*, and partly because, in common language, it is usual to understand by a "Batrachian" any of the higher Amphibians; such, for instance, as a Labyrinthodont.

The *Anoura*, or Tail-less Amphibians, are characterised by the following points:—The adult is destitute of both gills and tail, both of which structures exist in the larva, whilst the two pairs of limbs are always present. The skin is soft, and there are rarely any traces of an exoskeleton. The dorsal vertebræ are "procœlous" or concave in front, and are furnished with

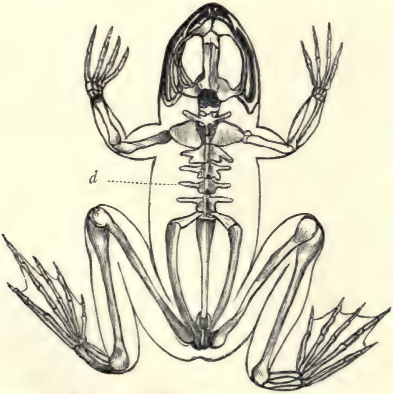


Fig. 308.—Skeleton of the common Frog (*Rana temporaria*). *d* Dorsal vertebræ, with long transverse processes.

long transverse processes, which take the place of ribs, which are only present in a rudimentary form. The radius and ulna in the fore-limb, and the tibia and fibula in the hind-limb, are

anchylosed to form single bones (fig. 308). The mouth is sometimes edentulous, but the upper jaw has usually small teeth, and the lower jaw sometimes. The hind-limbs usually have the digits webbed for swimming, and are generally much larger and longer than the fore-limbs.

The geological history of the *Anoura*, as in the case of the *Urodela*, is of small importance. The two chief groups of the living *Anoura*—namely, the Frogs and the Toads—are both represented in past time; but they do not appear to have come into existence till after the commencement of the Tertiary period. Most of the fossil forms have been detected in deposits of Miocene age.

ORDER IV. LABYRINTHODONTIA. — The members of this, the last order of the Amphibia, are entirely extinct. They were Batrachians, probably most nearly allied to the *Urodela*, but all of large size, and some of gigantic dimensions, the skull of one species (*Labyrinthodon Jægeri*) being upwards of three feet in length and two feet in breadth. The Labyrinthodonts were first known to science simply by their footprints, which were found in certain sandstones of the age of the Trias. These footprints consisted of a series of alternate pairs of hand-shaped impressions, the hinder print of each pair being much larger than the one in front (fig. 309). So like were these impressions to the shape of the human hand that the unknown animal which produced them was at once christened *Cheirotherium*, or "Hand-beast." Further discoveries, however, soon showed that the footprints of *Cheirotherium* had been produced by different species of Batrachians, to which the name of Labyrinthodonts was applied in consequence of the complex microscopic structure of the teeth.

The order *Labyrinthodontia* is thus defined by Professor Huxley:—"The body is salamandriform, with relatively weak limbs and a long tail. The dorsal vertebræ, when completely ossified, are biconcave, with double transverse processes. The ribs have distinct capitula and tubercula.

"In the thoracic region, three superficially sculptured exoskeletal plates, one median and two lateral, occupy the place of the interclavicle and clavicles. Between these and the pelvis is a peculiar armour, formed of rows of oval dermal plates, which lie on each side of the middle line of the abdomen, and are directed obliquely forwards and inwards, to meet in that line.

"The skull has distinctly ossified epiotic bones, in the same position and of the same form as those of fishes. The cranial bones are sculptured, and many exhibit peculiar smooth symmetrical grooves—the so-called 'mucous canals.'

"The parietes of the teeth are deeply plaited and folded, so as to give rise to a complicated 'labyrinthine' pattern in the transverse section of the tooth."

The points in which the Labyrinthodonts differ from the modern *Urodela* are chiefly to be found in the fact that the head is defended by an external covering or helmet of hard and polished osseous plates, in the possession of ventral integumentary scutes, in the existence of exoskeletal plates occupying the place of the interclavicle and clavicles, in the amphicœlous form

Fig. 309.—Foot-prints of a Labyrinthodont (*Cheirotherium*), from the Trias. The upper figure shows a single foot-print enlarged; the lower figure shows a slab, with several prints, and traversed by reticulated desiccation-cracks.

of the dorsal vertebræ, and in the complicated structure of the teeth. These last-mentioned organs are not only often very numerous, but are of large size. The subjoined illustration (fig. 310) shows the beautiful and complex structure of the teeth, from which the name of the order is derived.

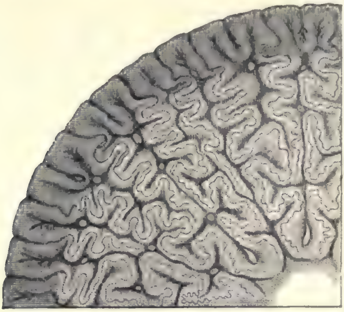


Fig. 310.—Section of the tooth of *Labyrinthodon* (*Mastodonsaurus*) *Jægeri*.

The Labyrinthodonts range from the Carboniferous Rocks to the Trias; but some of the forms commonly included in this order may perhaps belong elsewhere. One type of the Labyrinthodonts is constituted by the singular genus *Archegosaurus*, and the less known *Apateon*—both from the Carboniferous Rocks. *Archegosaurus* is remarkable in having the notochord persistent, and in the possession of permanent branchial arches. It has been made by Professor Owen the type of a separate group, the *Ganocephala;* but it is probably an immature and larval form. The occipital condyles, also, do not seem to have been ossified in the *Archegosauria*.

Of the Carboniferous Labyrinthodonts the most important genera are *Anthracosaurus*, *Pholidogaster*, *Ophiderpeton*, *Ichthyerpeton*, *Urocondylus*, *Lepterpeton*, *Baphetes*, *Raniceps*, *Dendrerpeton*, *Hylerpeton*, and *Hylonomus;* though the affinities of some of these are more or less doubtful. Most of the Carboniferous Labyrinthodonts were of comparatively small size; but some, such as *Baphetes* (fig. 311) and *Anthracosaurus*, must have attained gigantic dimensions. All the above-mentioned genera seem to have possessed well-ossified vertebræ, with well-developed limbs, the form of the body being mostly salamandriform, but sometimes fish-like, or serpentiform.

In the Permian Rocks, a few remains of Labyrinthodonts have been discovered, the genus *Zygosaurus* being peculiar to this period.

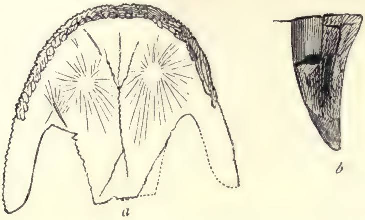


Fig. 311.—*Baphetes planiceps*, from the Carboniferous Rocks of Nova Scotia. (After Dawson.) *a* Anterior part of the skull, viewed from beneath, and much reduced; *b* One of the largest teeth, natural size.

In the Triassic Rocks the remains of Labyrinthodonts are abundant, the most important genus being *Labyrinthodon* or *Mastodonsaurus*. This genus is known mainly by foot-prints and by crania; and the size attained by some species must have been colossal. No remains of this order have hitherto been discovered in rocks younger than the Trias.

CHAPTER XXXII.

REPTILIA.

THE true Reptiles and the Birds, unlike as they are in external appearance, are nevertheless related to one another by various points of affinity; so that they may well be included in a single division, which has been termed *Sauropsida* by Huxley. The *Sauropsida* are defined by the possession of the following characters:—*At no period of existence are branchiæ, or water-breathing respiratory organs, developed upon the visceral arches; the red corpuscles of the blood are nucleated; the skull articulates with the vertebral column by means of a single articulating surface or condyle; and each half or "ramus" of the lower jaw is composed of several pieces, and articulates with the skull, not directly, but by the intervention of a peculiar bone, called the "quadrate bone," or "os quadratum"* (fig. 312).

These being the common characters of Reptiles and Birds, by which they are collectively distinguished from other Vertebrates, it remains to inquire what are the characters by which they are distinguished from one another. The following, then, are the characters which separate the Reptiles from the Birds: —*The blood in Reptiles is cold—that is to say, slightly warmer than the external medium—owing mainly to the fact that the pulmonary and systemic circulations are always directly connected together, either within the heart or in its immediate neighbourhood, so that the body is supplied with a mixture of venous and arterial blood, in place of pure arterial blood alone. The terminations of the bronchi at the surface of the lung are closed, and do not communicate with air-sacs, placed in different parts of the body. When the epidermis develops horny structures, these are in the form of horny plates or scales, and never in the form of feathers. The fore-limbs are formed for various purposes, including in some cases even flight, but they are never constructed upon the type of the "wings" of Birds. Lastly, with one or two doubtful exceptions, whilst the ankle-joint is placed between the distal and proximal portions of the tarsus, the tarsal and metatarsal bones of the hind-limb are never anchylosed into a single bone.*

These are the leading characters by which Reptiles are distinguished from Birds; but we must not forget the other distinctive peculiarities in which Reptiles agree with Birds, and differ from other Vertebrates—namely, the absence of branchiæ at all times of life, the possession of only one occipital condyle, and the articulation of the complex lower jaw with the skull by means of a quadrate bone.

It is now necessary to consider these characteristics of the *Reptilia* a little more minutely. The class includes the Tortoises and Turtles, the Snakes, the Lizards, the Crocodiles, and a number of extinct forms; and with the exception of the Tortoises and Turtles they are mostly of an elongated cylindrical shape, provided posteriorly with a long tail. The limbs may be altogether absent, as in the Snakes, or quite rudimentary, as in some of the Lizards, but as a general rule both pairs of limbs are present, sometimes in the form of ambulatory legs, sometimes as swimming-paddles, and in some extinct forms modified to subserve an aerial life. The endoskeleton is always well ossified, and is never cartilaginous or semi-cartilaginous, as in many Fishes and some Amphibians. The skull articulates with the atlas by a single condyle. The lower jaw is complex, each half or ramus being composed of from four to six pieces, united to one another by sutures (fig. 312). In the Tortoises, however, these are anchylosed into a single piece,

and the two rami are also anchylosed. In most Reptiles, however, the two rami of the lower jaw are only loosely united—in the Snakes by ligaments and muscles only, in the Lizards by fibro-cartilage, and in the *Crocodilia* by a regular suture. In all, the lower jaw articulates with the skull by a quadrate bone (fig. 312, *a*); and as this often projects backwards, the

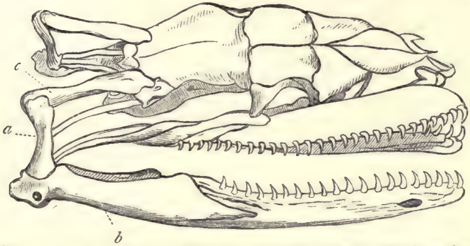


Fig. 312.—Skull of a Serpent (*Python*). *b* Articular portion of the lower jaw; *a* Quadrate bone; *c* Squamosal portion of the temporal bone.

opening of the mouth is often very extensive, and may even extend beyond the base of the skull. Teeth are usually present, but are not sunk in separate sockets or alveoli, except in the Crocodiles and in some extinct forms. In the Tortoises and Turtles alone of living types there are no teeth, and the jaws are simply sheathed in horn, constituting a kind of beak like that of a bird.

Ribs are always present and always well developed, but they differ much in form. It is not correct, however, to regard the presence of ribs as separating the true Reptiles from the *Amphibia*, as is sometimes stated. Some of the most Lizard-like of the Amphibians, such as the Siren, possess short but well-developed ribs, and rudiments of ribs are traceable in other orders; whilst in the *Cæciliæ* they are large and well developed.

As regards the exoskeleton, all Reptiles have horny epidermic scales, and they are divided into two great sections—called respectively *Squamata* and *Loricata*—according as the integumentary skeleton consists simply of these scales, or there are osseous plates developed in the derma as well. In the Tortoises, the epidermic plates unite with the bony exoskeleton and with the true endoskeleton to form the case or box in which the body of these animals is enclosed.

The class *Reptilia* is divided into the following nine orders, of which the first four are represented by living forms, whilst the remaining five are extinct:—

1. *Chelonia* (Tortoises and Turtles).
2. *Ophidia* (Snakes).
3. *Lacertilia* (Lizards).
4. *Crocodilia* (Crocodiles and Alligators).

} Recent.

5. *Ichthyopterygia.*
6. *Sauropterygia.*
7. *Anomodontia.*
8. *Pterosauria.*
9. *Deinosauria.*

} Extinct.

As regards their general *distribution in time*, the *Reptilia* attained their maximum of development in the Mesozoic period, which has hence often been called the "Age of Reptiles." If the Elgin Sandstones, containing the remains of *Telerpeton* and *Stagonolepis*, be of Triassic age—as seems almost certain—then no Reptile has as yet been discovered in the Devonian Rocks. In the Carboniferous Rocks, the place of the true Reptiles seems to have been taken by the Amphibian group of the Labyrinthodonts. It is possible, however, that the little *Hylonomus*, of which three species were discovered in the Coal-strata of Nova Scotia by Dr Dawson, may be Lacertian in its affinities. It is also possible that the vertebræ from strata of the same age described by Professor Marsh under the name of *Eosaurus Acadiensis*, may belong to a marine reptile allied to *Ichthyosaurus*. In the Permian Rocks the first undoubted Reptilian remains occur, the *Protorosaurus* of this period being probably a Lacertilian.

Throughout the whole Mesozoic series, Reptilian remains are abundant and belong to numerous and strange types. Chelonians and true Crocodiles, with Lizards allied to existing forms, make their first appearance in deposits belonging to this period. The extinct orders of the *Ichthyopterygia*, *Sauropterygia*, *Anomodontia*, *Pterosauria*, and *Deinosauria*, not only first appear in Mesozoic deposits, but are exclusively confined to rocks of this age. In the Tertiary period, lastly, the remains of Reptiles are comparatively rare, and the number of types is much reduced. The living order of the *Ophidia*, however, makes its first appearance in the Tertiary deposits. In the following view of the characters and distribution in time of the orders of the Reptiles, it will be advisable to consider the recent orders first, though this is not in accordance with their natural arrangement.

ORDER I. CHELONIA.—The first order of living Reptiles is that of the *Chelonia*, comprising the Tortoises and Turtles, and distinguished by the following characters:—There is an osseous exoskeleton which is combined with the endoskeleton to form

a kind of bony case or box in which the body of the animal is enclosed, and which is covered by a leathery skin, or, more usually, by horny epidermic plates. The dorsal vertebræ are immovably connected together, and are devoid of transverse processes. The ribs are greatly expanded (fig. 313, *r*), and

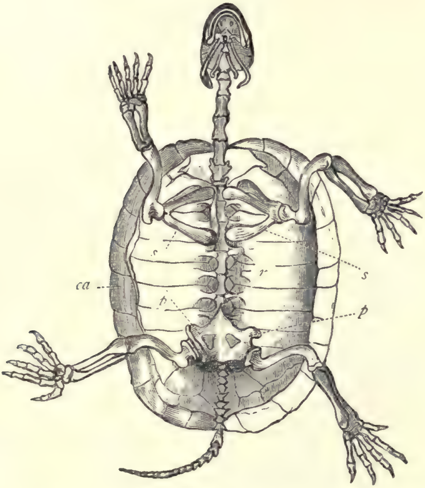


Fig. 313.—Skeleton of Tortoise (*Emys Europæa*,) the plastron being removed. *ca* Carapace; *r* Ribs, greatly expanded, and united by their edges; *s* Scapular arch, placed within the carapace, and carrying the fore-limbs; *p* Pelvic arch, also placed within the carapace, and carrying the hind-limbs.

are united to one another by sutures, so that the walls of the thoracic cavity are immovable. All the bones of the skull except the lower jaw and the hyoid bone are immovably united together. There are no teeth, and the jaws are encased in horn so as to form a kind of beak. The heart is three-chambered, the ventricular septum being imperfect.

Of these characters of the *Chelonia*, the most important and distinctive are the nature of the jaws, and the structure of the exoskeleton and skeleton. As regards the first of these points, the lower jaw in the adult appears to consist of a single piece, its complex character being masked by anchylosis. The separate pieces which really compose each ramus of the jaw are

immovably anchylosed together, and the two rami are also united in front by a true bony union. There are also no teeth, and the edges of the jaws are simply sheathed in horn, constituting a sharp beak. As regards the second of these points, the bony case in which the body of a Chelonian is enclosed consists essentially of two pieces, a superior or dorsal piece, generally convex, called the "carapace," and an inferior or ventral piece, generally flat or concave, called the "plastron." The carapace and plastron are firmly united along their edges, but are so excavated in front and behind as to leave apertures for the head, tail, and fore and hind limbs. The limbs and tail can almost always be withdrawn at will under the shelter of the thoracico-abdominal case formed in this way by the carapace and plastron, and the head is also generally retractile.

The carapace or dorsal shield is composed of the flattened spinous processes of the dorsal vertebræ, the expanded ribs, and usually a series of marginal bones—the whole covered by horny epidermic plates or by a leathery skin. The plastron or ventral shield is composed of nine bony pieces, which are probably integumentary ossifications, but which are sometimes regarded as composing a modified and greatly-expanded breast-bone. The scapular and pelvic arches, supporting respectively the fore and hind limbs, are placed within the carapace. As in the *Crocodilia*, clavicles are wanting.

From the aquatic habits of many of the members of this order they are by no means uncommon in the fossil condition. The Turtles frequent the sea, and thus come naturally to be fossils in marine deposits; and the preservation of all the Chelonians alike is rendered easy by the indestructible nature of the case in which their bodies are enclosed.

The Chelonians may be divided into sections according as the limbs are natatory, are adapted for an amphibious life, or are fitted for terrestrial progression. In the first of these sections are the true Turtles (*Cheloniidæ*), which frequent the sea, and are distinguished by their depressed and flattened carapace, and by their oar-like limbs. In the second section are the River and Marsh Tortoises, comprising the Soft Tortoises (*Trionycidæ*) and the Terrapins (*Emydidæ*). In the third section are the true Land-tortoises (*Testudinidæ*), distinguished by their strongly convex carapace, and limbs adapted for walking upon the land. All these three sections are represented in past time, the Turtles, *Trionycidæ*, and *Emydidæ* appearing for the first time, so far as is certainly known, in the Jurassic series, whilst the *Testudinidæ* do not appear till the

commencement of the Tertiary epoch. The earliest known traces of Chelonians occur in the Permian Rocks, in the lower portion, that is, of the New Red Sandstone of older geologists. These traces, however, are not wholly satisfactory, since they consist solely of the footprints of the animal upon the ripple-marked surfaces of the sandstone. Of this nature is the *Chelichnus Duncani*, described by Sir William Jardine in his classical work on the 'Ichnology' of Annandale in Dumfriesshire. With doubtful exceptions, the first unequivocal remains of Chelonians appear in the Jurassic series. The *Cheloniidæ* make their first undoubted appearance with the *Chelone planiceps* of the Portland stone (Upper Oolite). In the Cretaceous series are several turtles, one of which is figured below (fig. 314). In the Tertiary Rocks the remains of Turtles are abundant, and especially so in the London Clay (Eocene). Species of *Emydidæ* have been cited from the Jurassic series, some of which appear to be free from doubt. A species of *Emys* occurs in the Wealden, and numerous forms of this family have been detected in formations of Tertiary age, especially in the Eocene and Miocene. The *Trionycidæ*, except for a femur described by Owen from the Lias, are not known to have existed prior to the commencement of the Tertiary period. Numerous species of *Trionyx*, however, occur in the Eocene, and others have been described from the Miocene and Pliocene. The *Testudinidæ* or Land-tortoises appear to have commenced their existence in the Miocene Tertiary. The most remarkable form of this group is the great *Colossochelys Atlas* of the Tertiary deposits of the Sivalik Hills, which is believed to have reached the gigantic length of twenty feet.

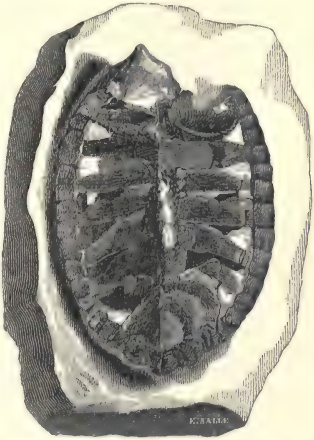


Fig. 314.—*Chelone Benstedi*. Lower Chalk.

ORDER II. OPHIDIA.—The second order of Reptiles is that of the *Ophidia*, comprising the Snakes and Serpents, and distinguished by the following characters :—

The body is always more or less elongated, cylindrical, and worm-like, and whilst possessing a covering of horny scales, is always unprovided with a bony exoskeleton. The dorsal vertebræ are concave in front (procœlous), with rudimentary transverse processes. There is never any sternum, nor pectoral arch, nor fore-limbs, nor sacrum, and as a rule there are no traces of hind-limbs. Rudimentary hind-limbs, however, are occasionally present (*e. g.*, in *Python* and *Tortrix*). There are always numerous ribs. The two halves or rami of the lower jaw are composed of several pieces, and the rami are united anteriorly by ligaments and muscles only, and not by cartilage or suture. The lower jaw, further, articulates with the skull by means of a quadrate bone (fig. 312, *a*), which is always more or less movable, and is in turn united with the squamous portion of the temporal bone ("mastoid bone"), which is also movable, and is not firmly united with the skull. The superior maxillæ are united with the præmaxillæ by ligaments and muscles only, and the palatine arches are movable and armed with pointed recurved teeth. Hooked conical teeth are always present, but they are never lodged in distinct sockets or alveoli. Functionally, they are capable of performing nothing more than merely holding the prey fast, and the Snakes are provided with no genuine masticatory apparatus. The heart has three chambers, two auricles and a ventricle, the latter imperfectly divided into two cavities by an incomplete septum. The lungs and other paired organs are mostly not bilaterally symmetrical, one of each pair being either rudimentary or absent.

The three most important groups of the existing Ophidians are the Colubrine Snakes, the Constricting Snakes, and the Viperine Snakes. In the first of these the upper jaws carry solid teeth, with or without canaliculated fangs as well. In the second group are the Boas and Pythons, distinguished by their great size, enormous muscular power, and numerous strong recurved teeth. In the third group are Snakes, in which the upper jaws carry only a pair of perforated poison-fangs.

Most of the existing Snakes are terrestrial in their habits, and are therefore not likely to be preserved in stratified deposits. Many of these, however, take to the water occasionally, and some habitually frequent rivers or the sea itself. All the above-mentioned groups of Ophidians are represented in past time, but they are neither abundant nor of importance as fossils. No remains of Ophidians are known to occur in any Palæozoic

or Mesozoic deposit. The earliest known traces of any serpent are in the Lower Kainozoic Rocks, the oldest being the *Palæophis toliapicus* of the London Clay of Sheppey. The nearly-allied *Palæophis typhæus* of the Eocene beds of Bracklesham appears to have been a Boa-constrictor-like snake of about twenty feet in length. Other species of *Palæophis* have been described from the Tertiary Rocks of the United States, and the genus *Dinophis* has been formed for the reception of another gigantic constricting Serpent from the same formation. In some of the later deposits have been found the poison-fangs of a venomous snake. Upon the whole, however, the Snakes must be looked upon as a comparatively modern group, and not as one of any great geological antiquity.

ORDER III. LACERTILIA.—The third order of Reptiles is that of the *Lacertilia*, comprising all those animals which are commonly known as Lizards, together with some serpentiform animals such as the Blind-worms. The *Lacertilia* are distinguished by the following characters:—

As a general rule, there are two pairs of well-developed limbs, but there may be only one pair, or all the limbs may be absent. A scapular arch is always present, whatever the condition of the limbs may be. An exoskeleton, in the form of horny scales like those of the Snakes, is almost always present. The vertebræ of the dorsal region are procœlous or concave in front, rarely amphicœlous or concave at both ends. There is a single transverse process at each side, and the heads of the ribs are simple and undivided. There is either no sacrum, or the sacral vertebræ do not exceed two in number. The teeth are not lodged in distinct sockets. The eyes are generally furnished with movable eyelids, and are always so in the completely snake-like forms. The heart consists of two auricles and a ventricle, the latter partially divided by an incomplete partition. There is a urinary bladder, and the aperture of the cloaca is transverse.

As a general rule, the animals included under this order have four well-developed legs, and would therefore be popularly called "Lizards." In some (*Chirotes*) there are no hind-feet; in some (*Bipes*) the fore-limbs are wanting; and others (*Anguis*, *Pseudopus*, and *Amphisbæna*) are entirely destitute of limbs, thus coming closely to resemble the true Snakes or Ophidians in external appearance. These serpentiform Lizards, however, can be distinguished from the true Snakes, amongst other characters, by the structure of the jaws. In the Snakes, as before said, the two rami of the lower jaw are loosely united in front by ligaments and muscles, and are

attached behind to a movable quadrate bone, which is in turn connected with a movable squamosal, this giving an enormous width of gape to these animals. In the Lizards, however, even in those most like the Snakes, the halves of the lower jaw are firmly united to one another in front, and though the quadrate bone is usually more or less movable, the jaws can in no case be separated to anything like the extent that characterises the *Ophidia*.

The Lizards are distinguished from the Crocodiles, amongst other characters, by the fact that the integumentary covering is in the form of horny scales, never with bony "scutes," whilst the teeth are rarely or never sunk into distinct sockets. In many cases the teeth are anchylosed to the summit of the margin of the jaw ("acrodont" dentition); in other cases they are attached by their sides to the inner surface of the jaw ("pleurodont" dentition).

The whole order of the *Lacertilia* is very often united with the next group of the *Crocodilia*, under the name of *Sauria*. The term "Saurian," however, is an exceedingly convenient one to designate all the reptiles which approach the typical Lizards in external configuration, whatever their exact nature may be; and from this point of view it is often very useful as applied to many fossil forms, the structure of which is only imperfectly known. It is therefore perhaps best to employ this term merely in a loose general sense.

It is hardly possible, with our present knowledge, to speak very positively as to the exact range of the *Lacertilia* in time. This uncertainty arises from two causes—firstly, that there is some doubt as to the exact age of some deposits which have yielded Lacertilian remains; and secondly, that the affinities of some extinct Reptiles are a matter of considerable question. Upon the whole, the oldest known Lacertilian would appear to be the *Protorosaurus* of the Middle Permian Rocks; though good authorities have placed this form in the Crocodilian group of the *Thecodontia*. *Protorosaurus* attained a length of between three and four feet, and differs from all existing Lizards in having its teeth implanted in distinct sockets—this being a Crocodilian character. In other respects, the Permian reptile approximates closely to the living Monitors (*Varanidæ*), and its slightly-cupped vertebræ would lead to the belief that it was aquatic in its habits.

In rocks known, or supposed, to be of Triassic age, numerous Lacertilian reptiles have been discovered, of which the most important are *Telerpeton*, *Hyperodapedon*, and *Rhynchosaurus*. *Telerpeton* occurs in strata near Elgin, in Scotland,

which have been variously referred to the Upper Devonian and to the Trias, but which almost certainly belong to the latter. Professor Huxley concludes that *Telerpeton* "presents not a single character approximating it towards the type of the Permian *Protosauria*, nor to the Triassic *Rhynchosaurus*, and other (probably Triassic) African and Asiatic allies of that genus, nor to the Mesozoic *Dinosauria;* still less can it be considered a 'generalised' form, or as, in any sense, a less perfectly organised creature than the Gecko, whose swift and noiseless run over walls and ceilings, surprises the traveller in warmer climates than our own." In its dentition, *Telerpeton* seems to have been "acrodont," and it differs from most existing Lizards merely in having amphicœlous, and not procœlous, vertebræ.

Hyperodapedon was originally discovered in the "Elgin Sandstones" along with *Telerpeton*, and it has since been found in strata of Triassic age in India. It was described by Professor Huxley as "a Saurian reptile about six feet long, remarkable for the flattened or slightly concave articular surfaces of the centra of its vertebræ, and for its well-developed costal system and fore and hind limbs; but more particularly characterised by its numerous series of sub-cylindrical palatal teeth." Upon the whole, Huxley concludes that *Hyperodapedon* is most nearly allied to the living *Sphenodon* (*Hatteria*) of New Zealand, upon the grounds that both "have amphicœlous vertebræ (those of the ancient reptile being far less fish-like than those of the modern one, be it noted); both have beak-like præmaxillæ, not anchylosed together; both have the inferior zygoma complete; both have similarly-formed lower jaws; in each a single row of teeth in the mandible bites between two rows of teeth fixed to a plate, which is formed by a union of the maxilla with the palatine bone—a structure which is quite anomalous amongst Lacertilians; and, finally, in both, these teeth wear down to the bone of the jaw by masticatory attrition."

The genus *Rhynchosaurus* is in a doubtful position, but may conveniently be considered here. By Huxley its affinities are regarded as being Lacertilian, but by Owen it is looked upon as belonging to the *Anomodontia*, and as being most nearly allied to *Oudenodon*. In many points *Rhynchosaurus* approaches the existing Lizards, but its vertebræ are amphicœlous, and the structure of the mouth is quite unlike that of any living Lacertilian. The skull

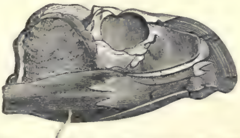


Fig. 315.—Skull of *Rhynchosaurus articeps*. (After Owen.) Trias.

(fig. 315) is pyramidal, and the jaws do not exhibit any traces of teeth. If the mouth be really edentulous, then *Rhynchosaurus* should probably be removed from the *Lacertilia*; but this point cannot in the meanwhile be definitely decided in the affirmative.

Amongst other Triassic, or supposed Triassic, Lacertilians, may be mentioned *Saurosternon* and *Pristerodon*, from strata believed to be of Triassic age in Africa, and *Clepsysaurus* and *Centemodon* from deposits of the same age in North America.

In the Jurassic period, the remains of Lacertilians are not unknown, but call for little special notice. Several forms of little importance have been described from the Middle Oolites. In the fresh-water strata of the Purbeck series (Upper Oolites), occur the remains which have been referred to the genera *Nuthetes*, *Macellodon*, *Saurillus*, and *Echinodon*. These are, perhaps, the first traces in the stratified series of remains, the affinities of which to the typical *Lacertidæ* cannot be disputed.

In the Cretaceous series occur the small Lizards which constitute the genera *Raphiosaurus*, *Coniosaurus*, and *Dolichosaurus*. Here also, and almost exclusively confined to strata of this age, occur the singular Lacertilians which form the group of the "Mosasauroids." These remarkable Reptiles were of gigantic size, *Mosasaurus princeps* being believed to have attained the enormous length of not less than seventy-five feet. The teeth in these reptiles (fig. 316) are long, pyramidal, and

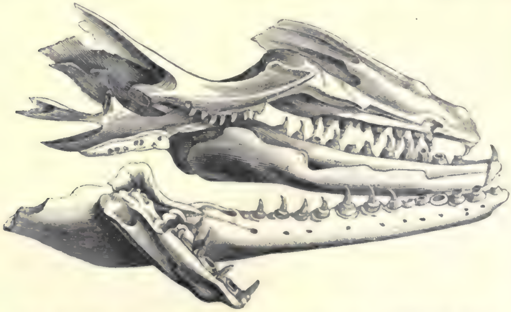


Fig. 316.—Skull of *Mosasaurus Camperi*, much reduced. Maestricht Chalk.

slightly curved; but they are anchylosed to the jaw, and are not sunk into distinct sockets, as in the living Crocodiles.

From the shortness of the humerus, and the indications that the vertebral column was unusually flexible, and that the tail was laterally compressed, it was early conjectured that the Mosasauroids were marine and aquatic in their habits. This conjecture has been raised to the rank of a certainty by the discovery that the fore and hind limbs of the Mosasauroids were in the form of fin-like paddles, like those of the Ichthyosaur and Plesiosaur. There can therefore be no doubt that *Mosasaurus*—like the living *Amblyrhynchus*—was aquatic in its habits, and frequented the sea-shore, coming, in fact, only occasionally to the land. The best-known genus is *Mosasaurus*, of which the most celebrated species is the *M. Camperi* (fig. 316) of the Maestricht Chalk. Other genera belonging to this group are *Leiodon*, *Baptosaurus*, and *Halisaurus*. Recently, Marsh has described bony dermal scutes as present in several Mosasauroids (*e.g.*, *Holcodus*, *Leiodon*, and *Edestosaurus*), thus rendering their Lacertilian affinities doubtful.

In the Tertiary Rocks the remains of Lacertilians are not by any means unknown, but none of the forms of this period are sufficiently important to demand especial attention. Most of the Tertiary Lacertilians, however, are of small size, and appear to have been terrestrial in their habits, thus approximating to the typical existing Lizards.

ORDER IV. CROCODILIA.—The last and highest order of the living *Reptilia* is that of the *Crocodilia*, including the living Crocodiles, Alligators, and Gavials, and characterised by the following peculiarities:—

The body is covered with an outer epidermic exoskeleton composed of horny scales, and an inner dermal exoskeleton consisting of squared bony plates or scutes, which may be confined to the dorsal surface alone, or may exist on the ventral surface as well, and which are disposed on the back of the neck into groups of different form and number in different species. The bones of the skull and face are firmly united together, and the two halves or rami of the lower jaw are united in front by a suture. There is a single row of teeth, which are implanted in distinct sockets, and hollowed at the base for the germs of the new teeth, by which they are successively pushed out and replaced during the life of the animal. The centra of the dorsal vertebræ in all living *Crocodilia* are procœlous, or concave in front, but in the extinct forms they may be either amphicœlous (concave at both ends) or opisthocœlous (concave behind). The vertebral ends of the anterior trunk-ribs are bifurcate. There are two sacral vertebræ. The cervical vertebræ have small ribs (hence the difficulty experienced by

the animal in turning quickly); and there are generally false abdominal ribs produced by the ossification of the tendinous intersections of the *recti* muscles. There are no clavicles. The heart consists of four completely distinct and separate cavities, two auricles, and two ventricles, the ventricular septum—as in no other Reptiles—being complete. The right and left aortæ, however, or, in other words, the pulmonary artery and systemic aorta, are connected together close to their origin by a small aperture (*foramen Panizzæ*), so that the two sides of the heart communicate with one another. The aperture of the cloaca is longitudinal, and not transverse, as in the Lizards. All the four limbs are present, the anterior ones being pentadactylous, the posterior tetradactylous. All are oviparous.

The chief points by which the Crocodiles are distinguished from their near allies, the Lacertilians, are the possession of a partial bony dermal exoskeleton in addition to the ordinary epidermic covering of scales, the lodgment of the teeth in distinct sockets, and the fact that the mixture of venous and arterial blood, which is so characteristic of Reptiles, takes place, not in the heart itself, but in its immediate neighbourhood, by a communication between the pulmonary artery and aorta directly after their origin.

The order Crocodilia is divided into three sub-orders, termed *Procœlia*, *Amphicœlia*, and *Opisthocœlia* according as the dorsal vertebræ are concave in front, concave at both ends, or concave behind. The sub-order *Procœlia* comprises all the living forms—namely, the Crocodiles proper, the Alligators, and the Gavials. The first of these have the fourth tooth in the lower jaw (fig. 317) larger than the others, forming a canine tooth,

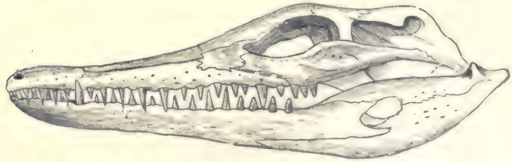


Fig. 317.—Skull of young *Crocodilus biporcatus* (after Van der Höven).

which is received into a notch excavated in the alveolar border of the upper jaw, so that it is visible externally when the mouth is closed. In the Alligators (fig. 318), the fourth tooth in the lower jaw forms a canine which is received into a pit in the palatal surface of the upper jaw, where it is completely concealed when the mouth is shut. In the Gavials the snout is

greatly prolonged, and the teeth are pretty nearly equal in size and similar in form in the two jaws.

The *Procœlian* Crocodiles occur for the first time in the Greensand (Cretaceous Series) of North America. In Europe, however, the earliest remains of Procœlian Crocodiles are from the Lower Tertiary Rocks (Eocene). It is a curious fact that in the Eocene Rocks of the south-west of England, there occur fossil remains of all the three living types of the *Crocodilia*—namely, the Gavials, true Crocodiles, and Alligators; though at the present day these forms are all geographically restricted in their range, and are never associated together.

Fig. 318.—Lower jaw of an Alligator. Eocene Tertiary, Isle of Wight.

The *Amphicœlian* Crocodiles are characterised by their biconcave vertebræ, and are entirely extinct, being confined altogether to the Mesozoic period. The biconcave vertebræ show a decided approach to the structure of the backbone in fishes; and as the rocks in which they occur are mostly marine, there can be little doubt but that these Crocodiles were, in the majority of cases at any rate, inhabitants of the sea. The typical members of this sub-order range from the Lias to the Chalk; and the most important genera are *Teleosaurus*, *Steneosaurus*, *Dakosaurus*, *Makrospondylus*, *Goniopholis*, and *Suchosaurus*, the two last mentioned occurring in the fresh-water deposits of the Wealden (Cretaceous).

The *Stagonolepis* of the Elgin Sandstone, with its pitted dermal bony scutes, is now believed to be truly referable to the *Crocodilia*. As before said, the Elgin Sandstones are probably Triassic.

We may briefly consider here a group of Reptiles which have been regarded as Crocodilian, but which are placed by Owen in a separate order under the name of *Thecodontia*, and which are looked upon by Huxley as being *Deinosaurian*. The

"Thecodont" Reptiles are defined as follows:—"Vertebral bodies biconcave; ribs of the trunk long and bent, the anterior ones with a bifurcate head; sacrum of three vertebræ; limbs ambulatory, femur with a third trochanter. Teeth with the crown more or less compressed, pointed, with trenchant and finely serrate margins, implanted in distinct sockets."—(Owen.)

The Thecodont Reptiles are Triassic, and the three most important genera are *Thecodontosaurus*, *Palæosaurus*, and *Belodon*, the last from undoubted Triassic strata, whilst the two former occur in a dolomitic conglomerate near Bristol, which has sometimes been thought to be Permian, but which is also almost certainly Triassic. In some respects these reptiles make an approach to the Lacertians; but, on the whole, little doubt can be entertained as to their truly belonging to the Amphicœlian Crocodiles.

The sub-order of the *Opisthocœlian* Crocodiles, including those forms in which the anterior trunk vertebræ are concave behind, is one which can be only provisionally retained. Professor Owen includes in this section the two genera *Streptospondylus* and *Cetiosaurus;* but the latter is referable to the *Deinosauria*, and will be treated of when that order is considered. The genus *Streptospondylus* has been founded on vertebræ obtained from the Oolitic and Wealden formations; but there are doubts as to the true position of the reptile to which these belonged.

CHAPTER XXXIII.

EXTINCT ORDERS OF REPTILES.

It remains now to consider briefly the leading characters of five wholly extinct orders of Reptiles, the peculiarities of which are very extraordinary, and are such as are exhibited by no living forms.

ORDER V. ICHTHYOPTERYGIA, Owen (= *Ichthyosauria*, Huxley).—The gigantic Saurians forming this order were distinguished by the following characters:—

The body was fish-like, without any distinct neck, and probably covered with a smooth or wrinkled skin, no horny or bony exoskeleton having been ever discovered. The vertebræ were numerous, deeply biconcave or amphicœlous, and having the neural arches united to the centra by a distinct suture. The anterior trunk-ribs possess bifurcate heads. There is no

sacrum, and no sternal ribs or sternum, but clavicles were present, as well as an interclavicle (episternum); and false ribs were developed in the walls of the abdomen. The skull had enormous orbits separated by a septum, and an elongated snout. The eyeball was protected by a ring of bony plates in the sclerotic. The teeth were not lodged in distinct sockets, but in a common alveolar groove. The fore and hind limbs were converted into swimming-paddles, the ordinary number of digits (five) remaining recognisable, but the phalanges being greatly increased in number, and marginal ossicles being added as well. A vertical caudal fin was in all probability present.

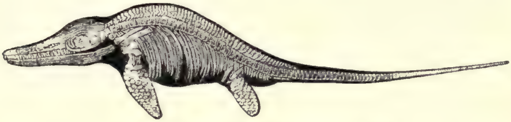


Fig. 319.—*Ichthyosaurus communis*. Lias.

The order *Ichthyopterygia* includes only the gigantic and fish-like *Ichthyosauri* (fig. 319), all exclusively Mesozoic, and abounding in the Lias, Oolites, and Chalk, but especially char-

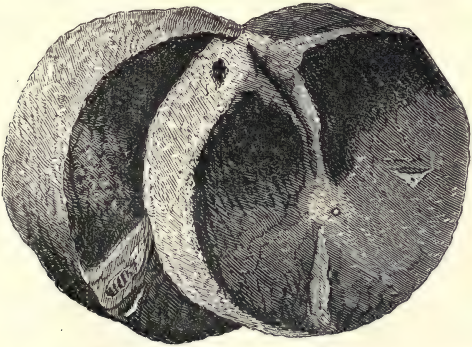


Fig. 320.—Two vertebræ of *Eosaurus Acadiensis* (Marsh). Coal-measures of Nova Scotia. (After Dawson.)

acteristic of the Lias. There is no doubt whatever but that the *Ichthyosauri* were essentially marine animals, and they have been often included with the next order (*Sauropterygia*) in a common group, under the name of *Enaliosauria* or Sea-lizards.

In 1861 Professor Marsh discovered in the Coal-measures of Nova Scotia two large amphicœlous vertebræ, which he described under the name of *Eosaurus Acadiensis*. These vertebræ (fig. 320) are of very large size (about two and a half inches in diameter), and they are deeply excavated at both ends. They are regarded by Professor Marsh as indicating the existence in the later Carboniferous period of a gigantic reptile allied to *Ichthyosaurus*. By Huxley, however, it is believed that these remains may truly belong to some large Labyrinthodont.

In the biconcave vertebræ and probable presence of a vertical tail-fin, the *Ichthyosaurus* approaches the true Fishes. There is, however, no doubt as to the fact that the animal was strictly an air-breather, and its reptilian characters cannot be questioned, at the same time that the conformation of the limbs is decidedly Cetacean in many respects. Much has been gathered from various sources as to the habits of the *Ichthyosaurus*, and its history is one of great interest. From the researches of Buckland, Conybeare, and Owen, the following facts appear to be pretty well established:—That the *Ichthyosauri* kept chiefly to open waters may be inferred from their strong and well-developed swimming-apparatus. That they occasionally had recourse to the shore, and crawled upon the beach, may be safely inferred from the presence of a strong and well-developed bony arch, supporting the fore-limbs, and closely resembling in structure the scapular arch of the *Ornithorhynchus* or Duck-mole of Australia. That they lived in stormy seas, or were in the habit of diving to considerable depths, is shown by the presence of a ring of bony plates in the sclerotic, protecting the eye from injury or pressure. That they possessed extraordinary powers of vision, especially in the dusk, is certain from the size of the pupil, and from the enormous width of the orbits. That they were carnivorous and predatory in the highest degree is shown by the wide mouth, the long jaws, and the numerous, powerful, and pointed teeth. This is proved, also, by an examination of their petrified droppings, which are known to geologists as "coprolites," and which contain numerous fragments of the scales and bones of the Ganoid fishes which inhabited the same seas.

ORDER VI. SAUROPTERYGIA, Owen (= *Plesiosauria*, Huxley).—This order of extinct reptiles, of which the well-known *Plesiosaurus* may be taken as the type, is characterised by the following peculiarities:—

The body, as far as is known, was naked, and not furnished with any horny or bony exoskeleton. The bodies of the ver-

tebræ were either flat or only slightly cupped at each end, and the neural arches were anchylosed with the centra, and did not remain distinct during life. The transverse processes of the vertebræ were long, and the anterior trunk-ribs had simple, not bifurcate, heads. No sternum or sternal ribs are known to have existed, but there were false abdominal ribs. The neck, in most, was greatly elongated, and composed of numerous vertebræ. The sacrum was composed of two vertebræ. The orbits were of large size, and there was a long snout, as in the *Ichthyosauri*, but there was no circle of bony plates in the sclerotic. The limbs agree with those of the *Ichthyosauri* in being in the form of swimming-paddles (fig. 321), but differ in not possessing any supernumerary marginal ossicles. A pectoral arch, formed of two clavicles and an interclavicle (episternum), appears to have been sometimes, if not always, present. The teeth were simple, and were inserted into distinct sockets, and not lodged in a common groove.

Fig. 321.—*Plesiosaurus dolichodeirus.* Lias.

The most familiar and typical member of the *Sauropterygia* is the *Plesiosaurus* (fig. 321), a gigantic marine reptile, chiefly characteristic of the Lias and Oolites. As regards the habits of the *Plesiosaurus*, Dr Conybeare arrives at the following conclusions:—"That it was aquatic is evident from the form of its paddles; that it was marine is almost equally so from the remains with which it is universally associated; that it may have occasionally visited the shore, the resemblance of its extremities to those of the Turtles may lead us to conjecture; its movements, however, must have been very awkward on land; and its long neck must have impeded its progress

through the water, presenting a striking contrast to the organisation which so admirably fits the *Ichthyosaurus* to cut through the waves." As its respiratory organs were such that it must of necessity have required to obtain air frequently, we may conclude "that it swam upon or near the surface, arching back its long neck like a swan, and occasionally darting it down at the fish which happened to float within its reach. It may perhaps have lurked in shoal water along the coast, concealed amongst the sea-weed; and raising its nostrils to a level with the surface from a considerable depth, may have found a secure retreat from the assaults of powerful enemies; while the length and flexibility of its neck may have compensated for the want of strength in its jaws, and its incapacity for swift motion through the water."

The geological range of the *Plesiosaurus* is from the Lias to the Chalk inclusive, and specimens have been found indicating a length of from eighteen to twenty feet.

About twenty species of *Plesiosaurus* have been described in all. Of the remaining genera of the *Sauropterygia*, *Nothosaurus*, *Simosaurus*, *Placodus*, *Pistosaurus*, and *Conchiosaurus* are Triassic. In *Nothosaurus* the neck is long, composed of at least twenty vertebræ. The dorsal vertebræ are biconcave, and the limbs are converted into swimming-paddles. The teeth are numerous and conical, and are implanted into distinct sockets. Several species are known, all Triassic, and especially characteristic of the Muschelkalk. *Simosaurus* had a large head with enormous orbits, and teeth sunk into distinct sockets. This genus is exclusively confined to the Muschelkalk. In *Placodus* (fig. 322), the teeth are in distinct sockets, and resemble those of many fishes in being rounded and obtuse, forming broad crushing plates adapted for the comminution of shell-fish. The upper jaw contains a double series of these teeth, an outer or maxillary series, and an internal or palatal series; but the under jaw has only a single row of teeth.

Fig. 322.—Under surface of the upper jaw in *Placodus gigas*. Muschelkalk.

Lastly, in *Pliosaurus* we have a huge reptile, allied to the *Plesiosaurus* in its fin-like paddles, but having an enormous head supported upon a short neck. The teeth are simple and conical, and in large speci-

mens attain a great size. *Pliosaurus* is confined to the Middle and Upper Oolites.

ORDER VII. ANOMODONTIA.—The members of this order are especially characterised by the structure of the mouth, the jaws being converted into a kind of beak, which was probably sheathed in horn, and resembled the jaws of a Turtle. Sometimes the mouth appears to have been wholly destitute of teeth, but in other cases there was a single pair of teeth implanted in the upper jaw, growing from persistent pulps, and assuming the character of great tusks. The dorsal vertebræ are biconcave, and the anterior trunk-ribs have bifurcate heads. The sacrum is large, composed of several vertebræ. The animal seems to have been organised for terrestrial progression, the pectoral and pelvic arches being strong, and the limbs well developed.

By Owen the genera *Dicynodon*, *Oudenodon*, and *Rhynchosaurus* are included in this order; but the last of these is regarded by Huxley as a Lacertilian. In *Dicynodon* (fig. 323,

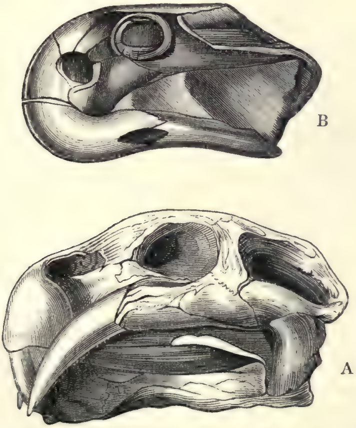


Fig. 323.—A, Skull of *Dicynodon lacerticeps*, showing the maxillary tusk. B, Skull of *Oudenodon Bainii*. From the Trias of South Africa. (After Owen.)

A), the anterior portions of the jaws appear to have been altogether toothless; and they form a kind of beak, which was probably sheathed in horn. The lower jaw has no teeth; but

each superior maxilla carries an enormous tusk-like tooth growing from a persistent pulp. In *Oudenodon*, on the other hand, the mouth is beak-shaped (fig. 323, B), and seems to have possessed no teeth of any kind. *Dicynodon* and *Oudenodon* are known only from strata of supposed Triassic age in India and South Africa. *Rhynchosaurus* also, if truly referable here, is Triassic, occurring in Europe.

ORDER VIII. PTEROSAURIA.—This order includes a group of extraordinary flying Reptiles, all belonging to the Mesozoic epoch, and exhibiting in many respects a very extraordinary combination of characters. The most familiar members of the order are the so-called "Pterodactyles," and the following are the characters of the order :—

No exoskeleton is known to have existed. The dorsal vertebræ are procœlous, and the anterior trunk-ribs are double-headed. There is a broad sternum with a median ridge or keel, and ossified sternal ribs. The jaws are always armed with teeth, and these were implanted in distinct sockets. In some forms (*Ramphorhynchus*) there appear to have been no teeth in the anterior portion of the jaws, and these parts seem to have been sheathed in horn, so as to constitute a kind of beak. A ring of bony plates occurs in the sclerotic coat of the eye. The pectoral arch consists of a scapula and distinct coracoid bone, articulating with the sternum as in Birds, but no clavicles have hitherto been discovered. The fore-limb (fig. 324) consists of a humerus, ulna and radius, carpus, and hand of four fingers, of which the inner three are short and unguiculate, whilst the outermost is clawless and is enormously elongated. Between this immensely-lengthened finger, the side of the body, and the comparatively small hind-limb, there must have been supported an expanded flying-membrane or "patagium," which the animal must have been able to employ as a wing, much as the Bats of the present day. Lastly, most of the bones were "pneumatic"—that is to say, were hollow and filled with air.

By the presence of teeth in distinct sockets, and, as will be seen hereafter, especially in the structure of the limbs, the Pterodactyles differed from all known Birds, and there can be little question as to their being genuine Reptiles. The only Reptile, however, now existing, which possesses any power of sustaining itself in the air, is the little *Draco volans*, but this can only take extended leaps from tree to tree, and cannot be said to have any power of flight properly so called. That the Pterodactyles, on the other hand, possessed the power of genuine flight, is shown by the presence of a median keel upon

the sternum, proving the existence of unusually-developed pectoral muscles; by the articulation of the coracoid bones with the top of the sternum, providing a fixed point or fulcrum for the action of the pectoral muscles; and, lastly, by the existence of air-cavities in the bones, giving the animal the necessary degree of lightness. The apparatus, however, of flight was not a "wing," as in Birds, but a flying-membrane, very similar in its mode of action to the patagium of the Mammalian order of the Bats. The patagium of the Bats, however, differs from that of the Pterodactyles in being supported by the greatly-elongated fingers, whereas in the latter it is only the outermost finger which is thus lengthened out.

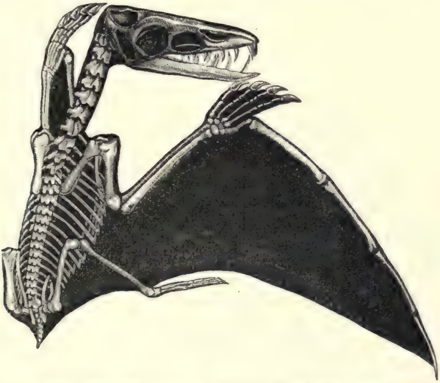


Fig. 324.—*Pterodactylus crassirostris.* From the Lithographic Slates of Solenhofen. (Upper Oolite).

The difficulty as to the position of the *Pterosauria* is evaded by Mr Seeley by placing them in a distinct class, which he terms *Ornithosauria*, and which he regards as most nearly related to, but coequal with, the class *Aves*.

The *Pterosauria* are exclusively Mesozoic, being found from the Lower Lias to the Middle Chalk inclusive, the Lithographic Slate of Solenhofen (Upper Oolite) being particularly rich in their remains. Most of them appear to have attained no very great size, but the remains of a species from the Cretaceous Rocks have been considered to indicate an animal with more than twenty feet expanse of wing, counting from tip to tip.

In the genus *Pterodactylus* proper, the jaws are provided

with teeth to their extremities, all the teeth being long and slender.

In *Dimorphodon*, the anterior teeth are large and pointed, the posterior teeth small and lancet-shaped.

In *Ramphorhynchus*, the anterior portion of both jaws is edentulous, and may have formed a horny beak, but teeth are present in the hinder portion of the jaws.

ORDER IX. DEINOSAURIA.—The last order of the Reptiles is that of the *Deinosauria*, comprising a group of very remarkable extinct forms, which are in some respects intermediate in their characters between the Cursorial birds and the typical Reptiles; whilst they have been supposed to have affinities to the Pachydermatous Mammals. Most of the *Deinosauria* were of gigantic size, and the order is defined by the following characters:—

The skin was sometimes naked, sometimes furnished with a well-developed exoskeleton, consisting of bony shields, much resembling those of the Crocodiles. A few of the anterior vertebræ were opisthocœlous, the remainder having flat or slightly biconcave bodies. The anterior trunk-ribs were double-headed. The teeth were confined to the jaws and implanted in distinct sockets. There were always two pairs of limbs, and these were strong, furnished with claws, and adapted for terrestrial progression. In some cases the fore-limbs were very small in proportion to the size of the hind-limbs. No clavicles have been discovered.

The teeth are sometimes implanted in distinct sockets, and they are never anchylosed with the jaws. The ischium and pubes are much elongated; the inner wall of the acetabulum is formed by membrane; the tibia has its proximal end prolonged anteriorly into a strong crest; and the astragalus is bird-like (Huxley).

The most remarkable points in the organisation of the *Deinosauria* are connected with the structure of the pelvis and hind-limb, the characters of which, as pointed out by Huxley, approximate to those of the same parts in the Birds, and especially in the Struthious Birds. This approximation is especially seen in the prolongation of the ilium in front of the acetabulum (fig. 325), the elongation and slenderness of form of the ischium, and the slenderness of the pubes. The astragalus is like that of a bird, and in some cases appears to have become anchylosed with the distal end of the tibia. The metatarsal bones, however, remain distinct, and are not anchylosed with any of the tarsal bones to form a "tarso-metatarsus."

The *Deinosauria* are exclusively Mesozoic, ranging from the Triassic to the Cretaceous formation, but abounding especially in the Oolitic and the earlier portion of the Cretaceous period. By Professor Huxley the "Thecodont" Reptiles are regarded as belonging here, as has been already remarked. The same high authority has also proposed the establishment of a new order termed *Ornithoscelida* to include the ordinary Deinosaurian Reptiles along with the singular *Compsognathus*.

A large number of generic types are included in the *Deinosauria*, of which *Iguanodon*, *Megalosaurus*, *Cetiosaurus*, and *Compsognathus* may be especially mentioned. Other less important forms are *Poikilopleuron*, *Lælaps*, *Euskelesaurus*, *Hylæosaurus*, *Hypsilophodon*, and *Hadrosaurus*.

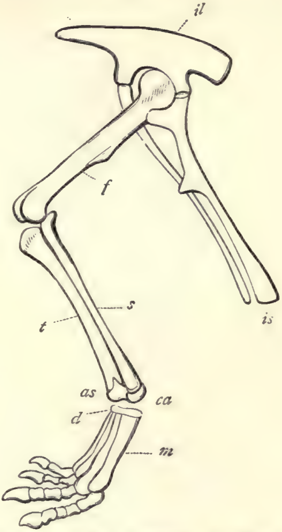


Fig. 325.—*Leg of Deinosaur.* *il* Ilium; *is* Ischium; *f* Femur; *t* Tibia; *s* Fibula; *as* Astragalus; *ca* Calcaneum; *m* Metatarsus. (After Huxley.)

The *Iguanodon* is mainly, if not exclusively, Cretaceous, being especially characteristic of the great delta-deposit of the Wealden. The length of the *Iguanodon* has been estimated as being probably from fifty to sixty feet, and from the close resemblance of its teeth to those of the living Iguanas, there is little doubt that it was herbivorous and not carnivorous. The femur of a large *Iguanodon* measures from four to five feet in length, with a circumference of twenty-two inches in its smallest part. From the disproportionately small size of the fore-limbs, and from the occurence of *pairs* of gigantic three-toed footsteps in the same beds, it has been concluded, with much probability, that *Iguanodon*, in spite of its enormous bulk, must have walked temporarily or permanently upon its hind-legs, thus coming to present a most marked and striking affinity to the Birds.

The teeth of *Iguanodon* (fig. 326) present a singularly close resemblance in shape to those of the comparatively pigmy Iguanas of the present day. Their crown is obtusely sub-triangular, with longitudinal ridges, and having the surface of the

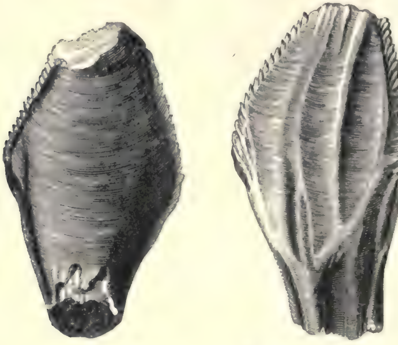


Fig 326.—Teeth of *Iguanodon Mantellii*. Wealden.

enamel crenated on one or both sides. They present the extraordinary feature that the crown became worn down flat by mastication, showing that *Iguanodon* employed the teeth in the actual trituration of the vegetable matter on which it fed.

The gigantic *Cetiosaurus* of the Oolitic and Cretaceous Rocks was originally placed amongst the *Crocodilia;* but the researches of Professor Phillips have shown that it belongs really to the *Deinosauria.* Having obtained a magnificent series of remains of this reptile, Professor Phillips has been able to determine many very interesting points as to the anatomy and habits of this colossal animal, the total length of which he estimates as being probably not less than sixty or seventy feet. As to its mode of life, this accomplished writer remarks :—

" Probably when ' standing at ease ' not less than ten feet in height, and of a bulk in proportion, this creature was unmatched in magnitude and physical strength by any of the largest inhabitants of the Mesozoic land or sea. Did it live in the sea, in fresh waters, or on the land ? This question cannot be answered, as in the case of Ichthyosaurus, by appeal to the accompanying organic remains ; for some of the bones lie

in marine deposits, others in situations marked by estuarine conditions, and, out of the Oxfordshire district, in Sussex, in fluviatile accumulations. Was it fitted to live exclusively in water? Such an idea was at one time entertained, in consequence of the biconcave character of the caudal vertebræ, and it is often suggested by the mere magnitude of the creature, which would seem to have an easier life while floating in water, than when painfully lifting its huge bulk, and moving with slow steps along the ground. But neither of these arguments is valid. The ancient earth was trodden by larger quadrupeds than our elephant; and the biconcave character of vertebræ, which is not uniform along the column in Cetiosaurus, is perhaps as much a character of a geological period as of a mechanical function of life. Good evidence of continual life in water is yielded in the case of Ichthyosaurus, and other Enaliosaurs, by the articulating surfaces of their limb-bones, for these, all of them, to the last phalanx, have that slight and indefinite adjustment of the bones, with much intervening cartilage, which fits the leg to be both a flexible and forcible instrument of natation, much superior to the ordinary oar-blade of the boatman. On the contrary, in Cetiosaur, as well as in Megalosaur and Iguanodon, all the articulations are definite, and made so as to correspond to determinate movements in particular directions, and these are such as to be suited for walking. In particular, the femur, by its head projecting freely from the acetabulum, seems to claim a movement of free stepping more parallel to the line of the body, and more approaching to the vertical than the sprawling gait of the crocodile. The large claws concur in this indication of terrestrial habits. But, on the other hand, these characters are not contrary to the belief that the animal may have been amphibious; and the great vertical height of the anterior part of the tail seems to support this explanation, but it does not go further. For the later caudal vertebræ, instead of being much compressed, as in Teleosaurus, are nearly circular in the cross section, and are interlocked by posterior zygapophyses, extended over half or the whole length of a vertebræ. We have therefore a marsh-loving or river-side animal, dwelling amidst filicine, cycadaceous, and coniferous shrubs and trees full of insects and small mammalia. What was its usual diet? If *ex ungue leonem*, surely *ex dente cibum*. We have indeed but one tooth, and that small and incomplete. It resembles more the tooth of Iguanodon than that of any other reptile; for this reason it seems probable that the animal was nourished by similar vegetable food which abounded in the vicinity, and was not obliged to

contend with Megalosaurus for a scanty supply of more stimulating diet."

Megalosaurus is a gigantic Oolitic Reptile, which occurs also in the Cretaceous series (Weald Clay). Its length has been estimated at between forty and fifty feet, the femur and tibia each measuring about three feet in length. As the head of the femur is set on nearly at right angles with the shaft, whilst all the long bones contain large medullary cavities, there can be no doubt but that *Megalosaurus* was terrestrial in its habits. That it was carnivorous and destructive in the highest degree is shown by the powerful, pointed, and trenchant teeth.

The teeth in *Megalosaurus* are conical, compressed, with finely-serrated edges. The fore-limbs are extraordinarily

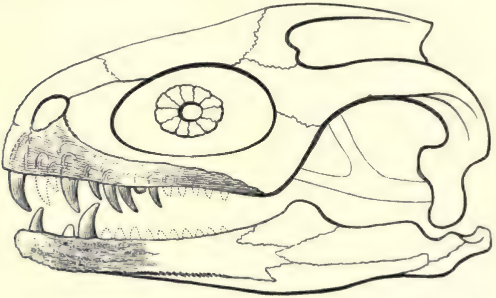


Fig. 327.—Cranium of *Megalosaurus*, restored. (After Professor Phillips.)

smaller than the hind-limbs. The teeth do not become worn by mastication; and there appears to have been no exoskeleton.

One of the most remarkable of the *Deinosauria* is the little *Compsognathus longipes* of the Lithographic Slate of Solenhofen, regarded by Professor Huxley as the type of a special group (*Compsognatha*) of his order *Ornithoscelida*. The special characters distinguishing this group are, that the cervical region of the spine is long, and the femur is shorter than the tibia; whereas in the typical *Deinosauria* the neck is relatively short, and the femur is as long as, or longer than, the tibia. *Compsognathus* is not remarkable for its size, which does not seem to have been much more than two feet, but for the striking affinities which it exhibits to the true Birds. The head of *Compsognathus* was furnished with *toothed* jaws, and supported

upon a long and slender neck. The fore-limbs were very short, but the hind-limbs were long and like those of Birds. The *proximal* portion of the tarsus resembled that of Birds in being anchylosed to the lower end of the tibia; but the *distal* portion of the tarsus—unlike that of Birds—was free, and was not anchylosed with the metatarsus. Huxley concludes that "it is impossible to look at the conformation of this strange Reptile, and to doubt that it hopped or walked in an erect or semi-erect position, after the manner of a bird, to which its long neck, slight head, and small anterior limbs must have given it an extraordinary resemblance."

CHAPTER XXXIV.

BIRDS.

THE fourth class of the *Vertebrata* is that of *Aves*, or Birds. The Birds may be shortly defined as being "oviparous Vertebrates with warm blood, a double circulation, and a covering of feathers" (Owen). More minutely, however, the Birds are defined by the possession of the following characters:—

The skull articulates with the vertebral column by a single occipital condyle. Each half or ramus of the lower jaw consists of a number of pieces, which are separate from one another in the embryo; and the jaw is united with the skull, not directly, but by the intervention of a quadrate bone (as in the Reptiles). The fore-limb in no existing birds possesses more than three fingers or digits, and the metacarpal bones are anchylosed together. In all living Birds the fore-limbs are useless as regards prehension, and in most they are organs of flight. The hind-limbs in all Birds have the ankle-joint placed in the middle of the tarsus, the proximal portion of the tarsus coalescing with the tibia, and the distal portion of the tarsus being anchylosed with the metatarsus to constitute a single bone known as the "tarso-metatarsus."

The heart consists of four chambers, two auricles and two ventricles; and not only are the right and left sides of the heart completely separated from one another, but there is no communication between the pulmonary and systemic circulations, as there is in Reptiles.

The respiratory organs are in the form of spongy cellular lungs, which are not freely suspended in pleural sacs; and the bronchi

open on their surface into a number of air-sacs, placed in different parts of the body.

All birds are oviparous, none bringing forth their young alive, or being even ovo-viviparous. All birds are, lastly, provided with an epidermic covering, so modified as to constitute what are known as feathers.

The entire *skeleton* of the Birds is singularly compact, and at the same time singularly light. The compactness is due to the presence of an unusual amount of phosphate of lime; and the lightness, to the absence in many of the bones of the ordinary marrow, and its replacement by air.

As regards the *vertebral column*, Birds exhibit some very interesting peculiarities. The cervical region of the spine is unusually long and flexible, since the fore-limbs are useless as organs of prehension—and all acts of grasping must be exercised either by the beak or by the hind-feet, or by both acting in conjunction. The number of vertebræ in the neck varies from nine to twenty-four, and their structure is always such as to allow of considerable freedom of motion one upon the other. The dorsal vertebræ vary from six to ten in number, and of these the anterior four or five are generally anchylosed with one another, so as to give a base of resistance to the wings. In the Cursorial Birds, however (such as the Ostrich and Emeu), and in some others (such as the Penguin), in which the power of flight is wanting, the dorsal vertebræ are all more or less freely movable one upon another. There are no lumbar vertebræ, but all the vertebræ between the last dorsal and the first caudal (varying from nine to twenty) are anchylosed together to form a bone which is ordinarily known as the "sacrum." To this, in turn, the iliac bones are anchylosed along its whole length, giving perfect immobility to this region of the spine and to the pelvis.

The coccygeal or caudal vertebræ vary in number from eight to ten, and are movable upon one another. The most noticeable feature about this part of the spinal column is what is known as the "ploughshare-bone." This is the last joint of the tail, and is a long, slender, ploughshare-shaped bone, destitute of lateral processes, and without any medullary canal (fig. 330, B). In reality it consists of two or more of the caudal vertebræ, completely anchylosed, and fused into a single mass. It is usually set on to the extremity of the spine at an angle more or less nearly perpendicular to the axis of the body; and it affords a firm basis for the support of the great quill-feathers of the tail ("rectrices"). In the Cursorial Birds, which do not fly, the terminal joint of the tail is not plough-

share-shaped. In the extraordinary Mesozoic bird, the *Archæopteryx macrura*, there is no ploughshare-bone, and the tail consists of twenty separate vertebræ, all distinct from one another, and each carrying a pair of quill-feathers, one on each side. As the vertebræ of the ploughshare-bone are distinct from one another in the embryos of existing birds, the tail of the *Archæopteryx* is to be regarded as a case of the permanent retention in the adult of an embryonic character. In the increased number of caudal vertebræ, however, and in some other characters, the tail of the *Archæopteryx* makes a decided approach to the true Reptiles.

The various bones which compose the *skull* of Birds are amalgamated in the adult so as to form a single piece, and the sutures even are obliterated, the lower jaw alone remaining movable. The occipital bone carries a single occipital condyle only, and this is hemispherical or nearly globular in shape. The "beak" (fig. 328), which forms such a conspicuous feature in all

Fig. 328.—Skull of Spur-winged Goose (*Plectropterus Gambensis*).

birds, consists of an upper and lower half, or a "superior" and "inferior mandible." The upper mandible is composed almost entirely of the greatly-elongated intermaxillary bones, flanked by the comparatively small superior maxillæ. The inferior mandible is primitively composed of twelve pieces, six on each side; but in the adult these are all indistinguishably amalgamated with one another, and the lower jaw forms a single piece. As in the Reptiles, the lower jaw articulates with the skull, not directly, but through the intervention of a distinct bone—the quadrate bone or tympanic bone—which always remains permanently movable, and is never anchylosed with the skull. In no bird are teeth ever developed in either jaw, but both mandibles are encased in horn, forming the beak, and the margins of the bill are sometimes serrated.

The thoracic cavity is bounded by the dorsal vertebræ, which

are usually, as before said, anchylosed with one another to a greater or less extent. Laterally, the thorax is bounded by the ribs, which vary in number from six to ten pairs. In most birds each rib carries a peculiar process—the "uncinate process"—which arises from its posterior margin, is directed upwards and backwards, and passes over the rib next in succession behind, where it is bound down by ligament. The first and last dorsal ribs carry no uncinate processes, and in some cases the processes continue throughout life as separate pieces (fig. 329, B). Anteriorly, the ribs articulate with a series of

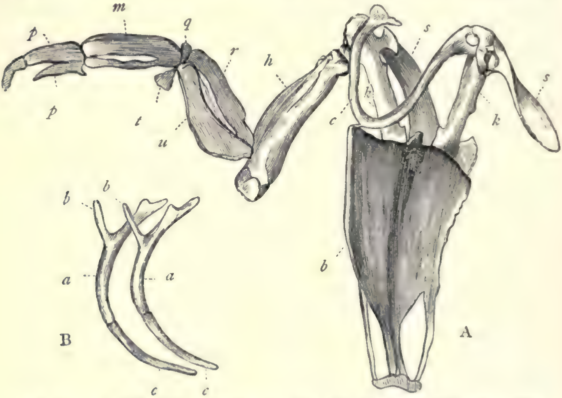


Fig. 329.—A, Breast-bone, shoulder-girdle, and fore-limb of Penguin (after Owen): *b* Sternum, with the sternal keel; *s s* Scapulæ; *k k* Coracoid bones; *c* Furculum or merry-thought, composed of the united clavicles; *h* Humerus; *u* Ulna; *r* Radius; *t* Thumb; *m* Metacarpus; *p* Phalanges of the fingers. B, Ribs of the Golden Eagle: *a a* Ribs giving off (*b b*) uncinate processes; *c c* Sternal ribs.

straight bones, which are called the "sternal ribs," but which in reality are to be looked upon as the ossified "costal cartilages." These sternal ribs (fig. 329, B) are in turn movably articulated to the sternum in front, and "they are the centres upon which the respiratory movements hinge" (Owen). In front the thoracic cavity is completed by an enormously-expanded sternum or breast-bone, which in some birds of great powers of flight extends over the abdominal cavity as well, in some cases even reaching the pelvis. The sternum of all birds which fly, is characterised by the presence of a greatly-developed median ridge or keel (fig. 329, A), to which are

attached the great pectoral muscles, which move the wings. As a general rule, the size of this sternal crest allows a very tolerable estimate to be formed of the flying powers of the bird to which it may have belonged; and in the Ostriches and other birds which do not fly, there is no sternal keel. At its anterior angles the sternum exhibits two pits for the attachment of the coracoid bones.

The scapular or pectoral arch consists of the shoulder-blade or scapula, the collar-bone or clavicle, and the coracoid bone, on each side. The scapula, as a rule (fig. 329, A, *s s*) is a simple elongated bone, not flattened out into a broad plate, and carrying no transverse ridge, or spinous process. Only a portion of the glenoid cavity for the articulation with the head of the humerus is formed by the scapula, the remainder being formed by the coracoid. The coracoid bones (fig. 329, A, *k k*) correspond with the coracoid processes of man, but in birds they are distinct bones, and are not anchylosed with the scapula. The coracoid bone on each side is always the strongest of the bones forming the scapular arch. Superiorly it articulates with the clavicle and scapula, and forms part of the glenoid cavity for the humerus. Inferiorly each coracoid bone articulates with the upper angle of the sternum. The position of the coracoids is more or less nearly vertical, so that they form fixed points for the action of the wings in their downward stroke. The clavicles (fig. 329, A, *c*) are rarely rudimentary or absent, and are in some few cases separate bones. In the great majority, however, of birds, the clavicles are anchylosed together at their anterior extremities, so as to form a single bone, somewhat V-shaped, popularly known as the "merry-thought," and technically called the "furculum." The outer extremities of the furculum articulate with the scapula and coracoid; and the anchylosed angle is commonly united by ligament to the top of the sternum. The function of the clavicular or furcular arch is "to oppose the forces which tend to press the humeri inwards towards the mesial plane, during the downward stroke of the wing" (Owen). Consequently the clavicles are stronger, and their angle of union is more open, in proportion to the powers of flight possessed by each bird.

As regards the structure of the wing proper, the humerus is short and strong, and articulates superiorly with an articular cavity formed partly by the coracoid and partly by the scapula. The fore-arm is composed of a radius and ulna, of which the former is the smallest and most slender. The carpus is reduced to two small bones wedged in between the distal end of the fore-arm and the metacarpus. The metacarpus consists of

two bones which in all existing birds are anchylosed at both ends, but which are free in the remarkable extinct *Archæopteryx.* The metacarpal, which corresponds to the radius, is the larger of the two, and it carries the digit which has the greatest number of phalanges. At the proximal end of the radial metacarpal is generally attached a single phalanx, constituting the so-called "thumb." The digit which is attached to the ulnar metacarpal never consists of more than a single phalanx.

As regards the structure of the posterior extremity or hind-limb, the pieces which compose the innominate bones (namely, the ilium, ischium, and pubes) are always anchylosed with one another; and the two innominate bones are also always anchylosed, by the medium of the greatly-elongated ilia, with the sacral region of the spine. In no living bird, however, with the single exception of the Ostrich, are the innominate bones united in the middle line in front by a symphysis pubis. The stability of the pelvic arch, necessary in animals which support the weight of the body on the hind-limbs alone, is amply secured in all ordinary cases by the anchylosis of the ilia with the sacrum.

As in the higher Vertebrates, the lower limb (fig. 330, A) consists of a femur, a tibia and fibula, a tarsus, metatarsus, and phalanges; but some of these parts are considerably obscured by anchylosis. The femur or thigh-bone (fig. 330, A, *f*) is generally very short, comparatively speaking. The chief bone of the leg is the tibia (*t*), to which a thin and tapering fibula (*r*) is anchylosed. The upper end of the fibula, however, articulates with the external condyle of the femur. The ankle-joint is placed, as in Reptiles, between the proximal and distal portions of the tarsus. The proximal portion of the tarsus is undistinguishably amalgamated with the lower end of the tibia. The distal portion of the tarsus is anchylosed with the whole of the metatarsus to constitute the most characteristic bone in the leg of the Bird—the "tarso-metatarsus" (*m*). In most of the long-legged birds, such as the Waders, the disproportionate length of the leg is given by an extraordinary elongation of the tarso-metatarsus.

The tarso-metatarsus is followed inferiorly by the digits of the foot. In most birds the foot consists of three toes directed forwards and one backwards—four toes in all. In no wild bird are there *more* than four toes, but often there are only three, and in the Ostrich the number is reduced to two. In all birds which have three anterior and one posterior toe, it is the posterior thumb or *hallux* (that is to say, the innermost digit of the hind-limb) which is directed backwards; and it

invariably consists of *two* phalanges only. The most internal of the three toes which are directed forwards, consists of *three* phalanges; the next has *four* phalanges; and the outermost toe is made up of *five* phalanges (fig. 330, A). This increase in an arithmetical ratio of the phalanges of the toes, in proceeding from the inner to the outer side of the foot, obtains in almost all birds, and enables us readily to detect which digit is suppressed, when the normal four are not all

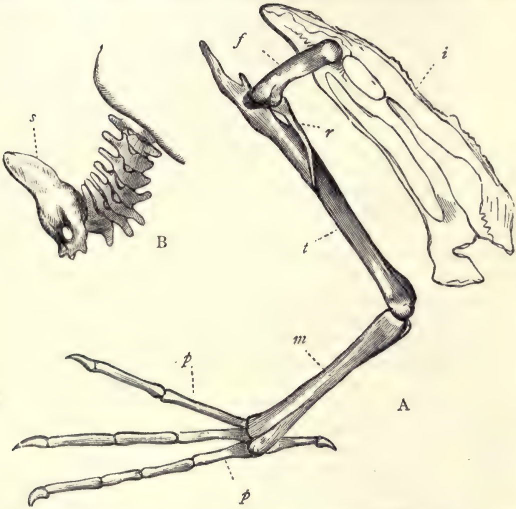


Fig. 330.—A, Hind-limb of the Loon (*Colymbus glacialis*)—after Owen: *i* Innominate bone; *f* Thigh-bone or femur; *t* Tibia, with the proximal portion of the tarsus anchylosed with its lower end; *r* Fibula; *m* Tarso-metatarsus, consisting of the distal portion of the tarsus anchylosed with the metatarsus; *p p* Phalanges of the toes. B, Tail of the Golden Eagle: *s* Ploughshare-bone, carrying the great tail-feathers.

present. Variations of different kinds exist, however, in the number and disposition of the toes. In many birds—such as the Parrots—the outermost toe is turned backwards, so that there are two toes in front and two behind. In others, again, the outer toe is normally directed forwards, but can be turned backwards at the will of the animal. In the Swifts, on the other hand, all four toes are present, but they are all turned forwards. In many cases—especially amongst the Natatorial

birds—the hallux is wholly wanting, or is rudimentary. In the Emeu, Cassowary, Bustards, and other genera, the hallux is invariably absent, and the foot is three-toed. In the Ostrich both the hallux and the next toe ("index") are wanting, and the foot consists simply of two toes, these being the outer toe and the one next to it.

As regards the *geological distribution* of Birds, there are many reasons why we should be cautious in reasoning upon merely negative evidence, and more than ordinarily careful not to infer the non-existence of birds during any particular geological epoch, simply because we can find no positive evidence for their presence. As Sir Charles Lyell has well remarked, "the powers of flight possessed by most birds would insure them against perishing by numerous casualties to which quadrupeds are exposed during floods;" and, "if they chance to be drowned, or to die when swimming on water, it will scarcely ever happen that they will be submerged so as to become preserved in sedimentary deposits," since, from the lightness of the bones, the carcase would remain long afloat, and would be liable to be devoured by predaceous animals. As, with a few utterly trivial exceptions, all the deposits in which fossils are found have been laid down in water, and more especially as they are for the most part marine, these considerations put forward by Sir Charles Lyell afford obvious ground against the anticipation that the remains of birds should be either of frequent occurrence or of a perfect character in any of the fossiliferous rocks. In accordance with these considerations, as a matter of fact, most of the known remains of birds are either fragmentary, or belong to forms which were organised to live a terrestrial life, and were not adapted for flight.

The earliest remains which have been generally referred to birds are in the form of footprints (fig. 331) impressed upon certain sandstones in the valley of the Connecticut River in the United States. These sandstones are almost certainly Triassic, and if the ornithic character of these footprints be admitted, then Birds date their existence from the commencement of the Mesozoic period, and, for anything we know to the contrary, may have existed during the Palæozoic epoch.

The evidence as to the ornithic character of the footprints in the American Trias is as follows:—

Firstly, The tracks are, beyond all question, those of a *biped*—that is to say, of an animal which walked upon two legs. No living animals walk habitually upon two legs except Man and Birds, and therefore there is a *primâ facie* presumption that the authors of these prints were birds.

Secondly, The impressions are mostly tridactylous—that is to say, formed by an animal with three toes on each foot, as is the case in many Waders and most Cursorial Birds.

Fig. 331.—Footprint supposed to belong to a Bird. Triassic Sandstones of Connecticut.

Thirdly, The impressions of the toes show the same numerical progression in the number of phalanges as exists in living birds—that is to say, the innermost of the anterior toes has three phalanges, the middle one has four, and the outermost toe has five phalanges.

Taking this evidence collectively, it would have seemed, till lately, tolerably certain that these impressions were formed by Birds. We must not, however, lose sight of the possibility that these impressions may have been formed by Reptiles more bird-like in their characters than any of the living forms with which we are acquainted. The recent researches of Huxley, Cope, and others, go to show that the *Deinosaurian* Reptiles possessed the power of walking, temporarily or permanently, on the hind-legs, and many curious affinities to the true Birds have been pointed out. It is therefore by no means impossible that these footprints of the Connecticut valley are truly Reptilian.*

The size and other characters of the above-mentioned impressions vary much, and they have certainly been produced

* The occurrence of many *four-toed* impressions in these same Sandstones, and the further discovery of the bones of Deinosaurian Reptiles in the same beds, have rendered the Reptilian nature of many of these footprints almost certain; but some may possibly have been formed by Birds.

by several different animals. In the largest hitherto discovered, each footprint is twenty-two inches long, and twelve inches wide, showing that the feet were four times as large as those of the African Ostrich. The animal, therefore, which produced these impressions—whether Avian or Reptilian—must have been of gigantic size.

The first unmistakable remains of a bird have been found in the Solenhofen Slates of Bavaria, of the age of the Upper Oolites. A single unique specimen, consisting of bones and feathers, but unfortunately without the skull, is all that has hitherto been discovered; and it has been named the *Archæopteryx macrura*. The characters of this singular and aberrant bird, which alone constitutes the order *Saururæ*, will be shortly given, and need not be repeated here.

Other doubtful remains of birds have been alleged to occur in the Mesozoic series, but many of these certainly belong in reality to Pterodactyles. In the Cretaceous Rocks, however, of the United States, occur the bones of several Wading Birds (*Laornis*, *Telmatornis*, and *Palæotringa*). Recently, Professor Marsh has described some additional remains of Birds from the Cretaceous Rocks. Some of these belong to a new genus, *Graculavus*, allied to the existing Cormorants. Others belong to a gigantic swimming bird of remarkable affinities, but having its nearest allies in the living *Colymbidæ*. The genus *Hesperornis* and family *Hesperornidæ* are proposed for its reception.

In the Tertiary Rocks there are, comparatively speaking, many remains of birds. In the Eocene Rocks of France has been found a large bird, as big as an Ostrich, the so-called *Gastornis Parisiensis;* and in England, in the same formation, we have a small Vulture (*Lithornis vulturinus*), and a Kingfisher (*Halcyornis toliapicus*). In the Eocene of Glaris, in Switzerland, occurs also the oldest known Insessorial or Passerine bird, the *Protornis Glarisiensis*, which was about as big as a lark.

Numerous remains of birds have likewise been found in the Miocene and Pliocene deposits. Amongst these we have Parrots, Trogons, Secretary Birds, Petrels, Cranes, Guillemots, &c. With the exception, however, of the Mesozoic *Archæopteryx*, by far the most remarkable remains of birds have been found in the Post-tertiary or Pleistocene deposits. All the remains now alluded to are those of gigantic wingless birds; and it is worthy of notice that they are almost exclusively found in regions now tenanted by smaller wingless birds, whilst there is reason to believe that some of them have been in existence during the human period. Most of the remains

in question have been found in New Zealand, where there have been obtained the bones of several species of large wingless birds, referred by Owen to the genera *Dinornis*, *Palapteryx*, and *Aptornis*. The *Dinornis giganteus* must have been one of the most gigantic of the whole class of birds, the tibia measuring upwards of a yard in length, and the skeleton indicating a bird which stood at least ten feet in height. In another species, the *Dinornis elephantopus*, the "framework of the skeleton is the most massive of any in the whole class of birds," and "the toe-bones almost rival those of the Elephant" (Owen). The feet were furnished with three anterior toes, and are of interest as presenting us with an undoubted bird big enough to produce the largest of the footprints of the Triassic Sandstones of Connecticut. There is reason to believe, from the traditions of the Maories, that the *Dinornis* was living at no very remote period, and that it has been exterminated by man.

In Madagascar, bones have been discovered of a bird as large as, or larger than, the *Dinornis giganteus*, which has been described under the name of the *Æpiornis maximus*. With the bones have been found eggs measuring from thirteen to fourteen inches in diameter, and computed to be as big as three ostrich-eggs, or one hundred and forty-eight hens' eggs. Unlike New Zealand, where there is the *Apteryx*, Madagascar itself has no living wingless birds; but in the neighbouring island of Mauritius the Dodo has been exterminated less than three hundred years ago; and the little island of Rodriguez, in the same geographical province, has in a similar period lost the wingless Solitaire (*Pezophaps*).

In the following are given the characters of the orders of the Birds, with the range of each in time, so far as known:—

ORDER I. NATATORES.—The order of the *Natatores*, or Swimmers, comprises a number of birds which are as much or even more at home in the water than upon the land. In accordance with their aquatic habit of life, the *Natatores* have a boat-shaped body, usually with a long neck. The legs are short, and placed behind the centre of gravity of the body, this position enabling them to act admirably as paddles, at the same time that it renders the gait upon dry land more or less awkward and shuffling. In all cases the toes are "webbed," or united by membrane to a greater or less extent. In many instances the membrane or web is stretched completely from toe to toe; but in others the web is divided or split up between the toes, so that the toes are fringed with membranous borders, and the feet are only imperfectly webbed.

Amongst the more important families of the *Natatores* may be enumerated the Penguins (*Spheniscidæ*), the Auks (*Alcidæ*), the Gulls and Terns (*Laridæ*), the Petrels (*Procellaridæ*), the Pelicans (*Pelicanus*), the Cormorants (*Phalacrocorax*), the Gannets (*Sula*), the Ducks (*Anatidæ*), the Geese (*Anserinæ*), and the Swans (*Cygnidæ*).

As might have been expected, the remains of Natatorial Birds are, speaking comparatively, not uncommon as fossils. The earliest traces of this order in past time appear in the Cretaceous series, which has yielded in Europe the *Cimolornis* (supposed to be allied to the Albatross), and in North America the genera *Graculavus*, *Hesperornis*, *Laornis*, *Telmatornis*, and *Palæotringa*. The Eocene Tertiary has a form believed to be nearly allied to the living Pelicans, and another supposed to be related to the Mergansers. The Ducks and Flamingos appear for the first time in the Miocene, and the Post-tertiary deposits have yielded remains of Geese, Gulls, Terns, Divers, and Guillemots, or of birds allied to these.

ORDER II. GRALLATORES.—The birds comprising the order of the *Grallatores*, or Waders, for the most part frequent the banks of rivers and lakes, the shores of estuaries, marshes, lagoons, and shallow pools, though some of them keep almost exclusively to dry land, preferring, however, moist and damp situations. In accordance with their semi-aquatic, amphibious habits, the Waders are distinguished by the great length of their legs; the increase in length being mainly due to the great elongation of the tarso-metatarsus. The legs are also unfeathered from the lower end of the tibia downwards. The toes are elongated and straight, and are never completely palmate, though sometimes semi-palmate. There are three anterior toes, and usually a short hallux, but the latter may be wanting. The wings are long, and the power of flight usually considerable; but the tail is short, and the long legs are stretched out behind in flight to compensate for the brevity of the tail. The body is generally slender, and the neck and beak usually of considerable length.

Amongst the more important Grallatorial Birds are the Rails (*Rallidæ*), Water-hens (*Gallinulæ*), Cranes (*Gruidæ*), Herons (*Ardeidæ*), Storks (*Ciconinæ*), Snipes (*Scolopacidæ*), Sandpipers (*Tringidæ*), Curlews (*Numenius*), Plovers (*Charadriidæ*), and Bustards (*Otidæ*).

As in the case of the *Natatores*, the earliest traces of the Waders appear to belong to the Cretaceous period. These consist of bones which have been referred to a Snipe-like bird (*Scolopax*), and which have been obtained from the Greensand

of New Jersey. In the Eocene Rocks, the most important form is the *Numenius gypsorum*, which has been discovered in the Gypseous series of Montmartre, and which is supposed to have been allied to the Ibis. In the later Tertiary deposits occur the remains of birds allied to, if not identical with, the living Cranes (*Grus*), Bustards (*Otis*), Rails (*Rallus*), and Coots (*Fulica*).

ORDER III. CURSORES.—The third order of Birds is that of the *Cursores*, or Runners, comprising the Ostriches, Rheas, Cassowaries, Emeus, and the singular *Apteryx* of New Zealand. In many respects the *Cursores* are to be looked upon as an artificial assemblage; but in the meanwhile it will be most convenient to consider them as forming a distinct division. The *Cursores* are characterised by the rudimentary condition of the wings, which are so short as to be useless for flight, and by the compensating length and strength of the legs. In accordance with this condition of the limbs, many of the bones retain their marrow, and the sternum is destitute of the prominent ridge or keel, to which the great pectoral muscles are attached (hence the name of *Ratitæ*, applied by Huxley to the

Fig. 332.—*Apteryx Australis.* (Gould.)

order). In the Ostrich, the pubic bones of the pelvis unite to form a symphysis pubis as they do in no other bird, and in all the pelvic arch possesses unusual strength and stability. The

legs are extremely robust and powerful, and the hind-toe is entirely wanting, except in the *Apteryx*, in which it is rudimentary. The anterior toes are two or three in number, and are provided with strong blunt claws or nails. The plumage presents the remarkable peculiarity that the barbs of the feathers, instead of being connected to one another by hooked barbules, as is usually the case, are remote and disconnected from one another, presenting some resemblance to hairs.

The living Cursorial Birds are the Ostrich (*Struthio camelus*), the American Ostriches (*Rhea*), the Emeu (*Dromaius*), the various species of Cassowary (*Casuarius*), and the *Apteryx* (fig. 332). Of the extinct forms of the *Cursores*, the most ancient appears to be the *Gastornis Parisiensis* of the Eocene Tertiary. This bird seems to have attained the size of an Ostrich, and it appears to have points of affinity with the Natatorial and Grallatorial Birds. In the superficial deposits of New Zealand have been found, as already mentioned, the remains of several species of *Dinornis* and *Palapteryx*, along with bones of the now existing *Apteryx*. In similar deposits in Madagascar occur the bones of the gigantic *Æpiornis*; and in the bone-caves of Brazil have been found remains of the American Ostriches or Rheas.

ORDER IV. RASORES.—The fourth order of Birds is that of the *Rasores*, or Scratchers, often spoken of collectively as the "Gallinaceous" Birds, from the old name of "Gallinæ," given to the order by Linnæus. The *Rasores* are characterised by the convex, vaulted upper mandible, having the nostrils pierced in a membranous space at its base. The nostrils are covered by a cartilaginous scale. The legs are strong and robust, mostly covered with feathers as far as the joint between the tibia and tarso-metatarsus. There are four toes, three in front and one behind, the latter being short, and placed generally at a higher level than the other toes. All the toes terminate in strong blunt claws suitable for scratching (*Gallinacei*), or in more slender claws adapted for perching (*Columbacei*). The order *Rasores* comprises the various species of Grouse (*Tetraonidæ*), the Partridges, Francolins, and Quails (*Perdicidæ*), the Turkeys, Fowls, Pheasants, and Pea-fowl (*Phasianidæ*), the Pigeons and Doves (*Columbidæ*), and the recently extinct Dodo (*Didus ineptus*).

The earliest remains of the Rasorial Birds appear in the Eocene Tertiary, where traces of a Partridge have been found. In Post-Tertiary deposits occur the remains of birds more or less closely allied to the existing Pigeons, Grouse, Quail, Pheasant, Fowl, and Tinamou.

ORDER V. SCANSORES.—The order of the Scansorial or Climbing Birds is easily and very shortly defined, having no other distinctive and exclusive peculiarity except the fact that the feet are provided with four toes, of which two are turned backwards and two forwards. Of the two toes which are directed backwards, one, of course, is the hallux, or proper hind-toe, and the other is the outermost of the normal three anterior toes. This arrangement of the toes enables the *Scansores* to climb with unusual facility. Their powers of flight, on the other hand, are generally only moderate and below the average.

The most important families of the *Scansores* are the Cuckoos (*Cuculidæ*), the Woodpeckers and Wry-necks (*Picidæ*), the Parrots (*Psittacidæ*), the Toucans (*Rhamphastidæ*), and the Trogons (*Trogonidæ*).

The Scansores are of small importance as fossils, but the remains of Parrots, Trogons, Woodpeckers, and Cuckoos have been detected in the later Tertiary and Post-tertiary deposits.

ORDER VI. INSESSORES.—The sixth order of Birds is that of the *Insessores*, or Perchers—often spoken of as the *Passeres*, or "Passerine" Birds. They are defined by Owen as follows :—

"Legs slender, short, with three toes before and one behind, the two external toes united by a very short membrane."

The *Insessores* form the largest order of existing birds, comprising all the ordinary "song-birds," and including a great number of families. The earliest known representatives of the order in past time are the *Protornis Glarisiensis* of the Eocene Schists of Glaris, and the *Halcyornis toliapicus* of the London Clay of Sheppey—the former somewhat resembling the living Larks, whilst the latter is supposed to be related to the Kingfishers. Besides these, a few unimportant forms have been discovered in the later Tertiary and Post-tertiary deposits.

ORDER VII. RAPTORES.—All the members of this order are characterised by the shape of the bill, which is "strong, curved, sharp-edged, and sharp-pointed, often armed with a lateral tooth" (Owen). The upper mandible is the longest, and is strongly hooked at the tip. The body is very muscular; the legs are robust, short, with three toes in front and one behind, all armed with long, curved, crooked claws or talons; the wings are commonly pointed, and of considerable size, and the flight is usually rapid and powerful.

The order *Raptores* is divided into the two sections of the *Nocturnal* and *Diurnal Raptores*, comprising respectively the forms which fly by night and those which fly by day. In the

former are only the Owls, and in the latter are the Hawks, Falcons, Eagles, and Vultures. The earliest representative of the *Raptores* in past time is the *Lithornis vulturinus* of the London Clay of Sheppey, a bird probably related to the existing vultures. In the Gypseous series of Montmartre (Eocene), there are also remains of an Owl (*Strix*), and of a Harrier (*Circus*). In later Tertiary and Post-tertiary deposits occur unimportant remains of Eagles, Hawks, and Vultures.

ORDER VIII. SAURURÆ.—This order includes only the extinct bird, the *Archæopteryx macrura*, a single specimen of which—and that but a fragmentary one—has been discovered in the Lithographic Slates of Solenhofen (Upper Oolites). This extraordinary bird (fig. 333), appears to have been about as big as a Rook; but it differs from all known birds in having two free claws belonging to the wing, and in having a long lizard-like tail, longer than the body, and composed of separate vertebræ.

Fig. 333.—*Archæopteryx macrura*, showing tail and tail-feathers, with detached bones.

The tail was destitute of any ploughshare-bone, and each vertebra carried a single pair of quill-feathers. The metacarpal bones also were not anchylosed, as they are in all other known birds, living or extinct. Milne Edwards concludes that *Archæopteryx* was probably a vegetable feeder, and that it ordinarily perched upon trees.

CHAPTER XXXV.

MAMMALIA.

General Characters of the Mammalia.

The last and highest class of the *Vertebrata*, that of the *Mammalia*, may be shortly defined as including *Vertebrate animals in which some part or other of the integument is always provided with hairs at some time of life; and the young are nourished for a longer or shorter time, by means of a special fluid—the milk—secreted by special glands—the mammary glands.* These two characters are of themselves sufficient broadly to separate the Mammals from all other classes of the Vertebrate sub-kingdom. In addition, however, to these two leading peculiarities, the Mammals exhibit the following other characters of scarcely less importance:—

1. The skull articulates with the vertebral column by means of a double articulation, the occipital bone carrying two condyles, in place of the single condyle of the Reptiles and Birds.

2. The lower jaw or mandible consists of two halves or rami, united anteriorly by a symphysis, but not necessarily anchylosed; but these are each composed of a single piece, instead of being complex and consisting of several pieces, as in the Reptiles and Birds. Further, the lower jaw always articulates directly with the squamosal element of the skull, and is never united to an os quadratum, as in the *Sauropsida*.

3. The two hemispheres of the cerebral mass, or brain proper, are united together by a more or less extensively developed "corpus callosum" or commissure.

4. The heart consists—as in Birds—of four cavities or chambers, two auricles and two ventricles. The right and left sides of the heart are completely separated from one another, and there is no communication between the pulmonary and systemic circulations.

5. The cavities of the thorax and abdomen are completely separated from one another by a muscular partition—the diaphragm or midriff.

6. The respiratory organs are in the form of two lungs placed in the thorax, but none of the bronchi end in air-receptacles, distributed through the body, as in Birds.

As regards the *Osteology* of the Mammals, the following points should be noticed:—

With the exception of the Whales and Dolphins (*Cetacea*),

and the Dugongs and Manatees (*Sirenia*), the vertebral column is divisible into the same regions as in man—namely, into a cervical, dorsal, lumbar, sacral, and caudal or coccygeal region (see fig. 269). In the *Cetacea* and *Sirenia* the dorsal region of the spine is followed by a number of vertebræ which compose the hinder extremity of the body, but which cannot be separated into lumbar, sacral, and caudal vertebræ.

In spite of the great difference which is observable in the length of the neck in different Mammals, the number of vertebræ in the cervical region is extraordinarily constant, being almost invariably seven, as in man. In this respect there is no difference between the Whale and the Giraffe. The only exceptions to this law are the *Manatus australis*, one of the Sea-cows, which has usually six cervical vertebræ; and the three-toed Sloth (*Bradypus tridactylus*), which is commonly regarded as possessing nine, though competent anatomists would refer the posterior two of these to the dorsal region.

The dorsal vertebræ are mostly thirteen in number, but they vary from ten to twenty-four. In Man there are twelve, in one of the Armadillos only ten, and in the three-fingered Sloth the maximum is attained. The lumbar vertebræ are usually six or seven in number, rarely fewer than four. In Man they are five in number, and they are reduced to two in the two-toed Sloth, one of the Ant-eaters, and the Duck-mole.

The first vertebra, or atlas, always bears two articular cavities for the reception of the two condyles of the occipital bone, and the second vertebra, or axis, usually has an "odontoid" process on which the head rotates. In the true Whales, however, in which the cervical vertebræ are anchylosed together to a greater or less extent, and the neck is immovable, the odontoid process is also wanting.

The number of lumbar and sacral vertebræ, as we have seen, varies in different Mammals; but ordinarily some of the vertebræ are anchylosed into a single bone, and have the iliac bones abutting against them, thus constituting the "sacrum" of human anatomists. In the *Cetacea* and *Sirenia*, in which the hind-limbs are wanting, and the pelvis rudimentary, there is no "sacrum."

The thoracic cavity or chest in Mammals is always enclosed by a series of ribs, the number of which varies with that of the dorsal vertebræ. In most cases each rib articulates by its head with the bodies of *two* vertebræ, and by its tubercle with the transverse process of one of these vertebræ (the lower one). In the *Monotremata* (*e.g.*, the Duck-mole), the ribs articulate with the body of the vertebra only; and in the Whales, the

hindermost of the ribs, or all of them, articulate with the transverse processes only, and not with the centra at all.

There are usually no bony pieces uniting the ribs with the sternum or breast-bone in front, as in Birds ; but the so-called "sternal ribs" of *Aves* are represented by the "costal cartilages" of the Mammals. In some cases, however, the cartilages of the ribs do become ossified and constitute sternal ribs. Sometimes, as in the Armadillos, there is a joint between the vertebral rib and costal cartilage. More rarely, as in the *Monotremes*, an intermediate piece is found between the vertebral and costal portions of the rib. Only the anterior ribs reach the sternum, and these are called the "true" ribs; the posterior ribs, which fall short of the breast-bone, being known as the "false" ribs.

The sternum or breast-bone is formed of several pieces placed one behind the other, but usually anchylosed together to form a single bone. It is placed upon the ventral surface of the body, and is united with the vertebral column by the ribs and their cartilages. It is generally a long and narrow bone, but in the *Cetacea* it is broad. It is only in some burrowing animals (such as the Moles) and in the true flying Mammals (the Bats), that the sternum is provided with any ridge or keel for the attachment of the pectoral muscles, as it is in Birds. The sternum is primitively composed of three pieces, an anterior piece or *præsternum*, a middle piece or *mesosternum*, and a posterior piece or *xiphisternum*. The præsternum is the "manubrium sterni" of human anatomy, and is the portion of the sternum which lies in front of the attachment of the second pair of ribs. All the other ribs are connected with the mesosternum. The *xiphisternum* is the "xiphoid cartilage" of human anatomy, and it commonly remains throughout life more or less unossified. In the Monotremes there is a T-shaped bone above or in front of the præsternum, but this is probably to be regarded as belonging to the shoulder-girdle, and as representing the "episternum" or "interclavicle" of the Reptiles.

The normal number of limbs in the *Mammalia* is four, two anterior and two posterior; and hence they are often spoken of as "quadrupeds," though all the limbs are not universally present, and other animals have four limbs as well. The anterior limbs are not known to be wanting in any Mammal, but the posterior limbs are absent in the *Cetacea* and *Sirenia*.

As regards the structure of the anterior limb, the chief points to be noticed concern the means by which it is connected with the trunk. The scapula or shoulder-blade is never absent, and it is in the form of a broad flat bone, applied to the

outer aspect of the ribs, and much more developed than in the Birds. The coracoid bone, which forms such a marked feature in the scapular arch of *Aves*, is fused with the scapula, and only articulates with the sternum in the Duck-mole and Echidna (*Monotremata*). In all other Mammals the coracoid forms merely a process of the scapula, and does not reach the top of the breast-bone. The collar-bones or clavicles never unite in any Mammal to form a "furculum," as in Birds; but in the Monotremes they unite with an "inter-clavicle" placed in front of the sternum. The clavicles, in point of fact, are not present in a well-developed form in any Mammals except in those which use the anterior limbs in flight, in digging, or in prehension. The *Cetacea*, the Hoofed Quadrupeds (*Ungulata*), and some of the *Edentata*, have no clavicles. Most of the *Carnivora* and some Rodents possess a clavicle, but this is imperfect, and does not articulate with the top of the sternum. The Insectivorous Mammals, many of the Rodents, the Bats, and all the *Quadrumana*, have (with man) a perfect clavicle articulating with the anterior end of the sternum.

The humerus, or long bone of the upper arm (*brachium*), is never wanting, but is extremely short in the Whales, in which the anterior limbs are converted into swimming-paddles.

In the fore-arm of all Mammals the ulna and radius are recognisable, but they are not necessarily distinct; and the radius, as being the bone which mainly supports the hand, is the only one which is always well developed, the ulna being often rudimentary. In the *Cetacea* the ulna and radius are anchylosed together; and in most of the Hoofed Quadrupeds they are anchylosed towards their distal extremities.

The fore-arm is succeeded by the small bones which compose the wrist or "carpus." These are eight in number in man, but vary in different Mammals from five to eleven.

The metacarpus in man and in most Mammals consists of five cylindrical bones, articulating proximally with the carpus, and distally with the phalanges of the fingers. The most remarkable modification of this normal state of things occurs in the Ruminants and in the Horse. In the Ruminants, in which the foot is cleft, and consists of two perfect toes only, there are two metacarpal bones in the embryo; but these are anchylosed together in the adult, and form a single mass which is known as the "canon-bone" (fig. 334, *ca*). In the Horse, in which the foot consists of no more than a single digit, there is only a single metacarpal bone, on each side of which are two little bony spines—the so-called "splint-bones"—which are attached superiorly to the carpus. These are to be regarded as rudi-

mentary metacarpals; but by Cuvier they were looked upon as imperfect fingers. In most of the other Ungulates there are at least three metacarpals, and in the Elephants there are five.

The normal number of digits is five, but they vary from one to five. The middle finger is the longest and most persistent of the digits of the fore-limb; and in the Horse it is the only one which is left (fig. 334, A). The thumb is very frequently absent. In the Ruminants there are only two fingers which are functionally useful, these carrying the hoofs. In many Ruminants, however, there are two rudimentary and functionally useless digits in addition.

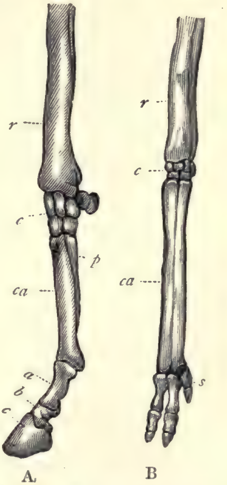


Fig. 334.—A, Fore-leg of the Horse: *r* Radius; *c* Carpus; *ca* Canon-bone; *p* Splint-bone; *a* First phalanx or "great pastern;" *b* Second phalanx or "small pastern;" *c* Ungual phalanx or "coffin-bone." B, Fore-limb of a Deer: *r* Radius; *c* Carpus; *ca* Canon-bone; *s* Supplementary toe.

Normally each digit has three phalanges, except the thumb, which has only two. In the Whales and Dolphins (*Cetacea*), in which the anterior limbs form swimming-paddles very like those of the *Ichthyosaurus* and *Plesiosaurus*, the phalanges are considerably increased in number as they are in those Reptiles. In all the Mammalia, too, except the *Cetacea*, it is the rule that the terminal phalanx in each digit should carry a nail, claw, or hoof.

Whilst the anterior limbs are never absent in any Mammal, the posterior limbs are occasionally wholly wanting, as in the *Cetacea* and *Sirenia*. Generally speaking, however, the posterior limbs are present, and the pelvic arch has much the same structure as in man. The two halves of the pelvis—the ossa innominata—consist each of three pieces in the embryo (viz., the ilium, ischium, and pubes), which meet to form the cup-shaped cavity known as the "acetabulum," with which the head of the thigh-bone articulates. In the adult Mammal these three bones are anchylosed together, and the two ossa innominata unite in front by means of a symphysis pubis, constituted either by a cartilaginous union (synchondrosis), or by

merely ligamentous attachment. In some Mammals, however, such as the Mole, and many of the Bats, the pubic bones remain disunited during life. As a rule also, the ossa innominata are firmly united with the vertebral column. In the Cetaceans, in which the hind-limbs are wanting, and there is no sacrum, the innominate bones are rudimentary, and are not attached in any way to the spine.

The only other bones which are ever connected with the pelvis are two small bones which are directed upwards from the brim of the pelvic cavity in Marsupials and Monotremes. These are the so-called "marsupial bones" regarded generally as not forming parts of the skeleton properly so called, but as being ossifications of the internal tendons of the "external oblique" muscles of the abdomen (fig. 336).

In those Mammals which possess hind-limbs, the normal composition of the member is of the following parts:—1. A thigh-bone or femur; 2. Two bones forming the shank, and known as the tibia and fibula; 3. A number of small bones constituting the ankle or tarsus; 4. The "root" of the foot, made up of the "metatarsus;" 5. The phalanges of the toes (see fig. 271).

The thigh-bone or femur articulates with the pelvis, usually at a very open angle. In Man it is distinguished by being the longest bone of the body, and by having the axis of its shaft nearly parallel to that of the vertebral column. In most Mammals the femur is relatively shorter, and the axis of its shaft deviates considerably from that of the spine, being sometimes at right angles, or even at an acute angle.

Of the bones of the leg proper the tibia corresponds to the radius in the fore-limb, as shown by its carrying the tarsus; and the fibula is the representative of the ulna. The articulation between the tibia and fibula on the one hand, and the femur on the other, constitutes the "knee-joint," which is usually defended in front by the "knee-pan" or patella, a large sesamoid bone developed in the tendons of the great extensor muscles of the thigh. The patella is of small size in the *Carnivora*, but does not appear to be wanting in any except the Marsupials. In many cases the tibia and fibula are anchylosed towards their distal extremities. In the Horse the fibula has much the same character as in Birds, being a long splint-like bone which only extends about half-way down the tibia. In the Ruminants the reverse of this obtains, the upper half of the fibula being absent, and only the lower half present.

The tibia articulates with the tarsus, consisting in Man of seven bones, but varying in different Mammals from four to nine.

The foot consists normally of five toes connected with the tarsus by means of five metatarsal bones, which closely resemble the metacarpals. In the Ruminants there are only two metatarsals, and these are anchylosed in the adult, and carry two toes. In the Horse there is only one complete metatarsal supporting a single toe. As a rule, the number of digits in the hind-limb or foot is the same as that in the fore-limb or hand; but this is not always the case.

The cranial bones are invariably connected with one another by sutures, and in no other examples than the Monotremes are these sutures obliterated in the adult. The occipital bone carries two condyles for articulation with the first cervical vertebra. The lower jaw is composed of two halves or rami, which are distinct from another in the embryo, and may or may not be anchylosed together in the adult. However this may be, in no Mammal is the ramus of the lower jaw composed of several pieces, as it is in Birds and Reptiles, nor does it articulate with the skull by the intervention of an os quadratum. On the other hand, each ramus of the lower jaw in the Mammals is composed of only a single piece, and articulates with the squamosal element of the skull, or, in other words, with the squamous portion of the temporal bone.

Teeth are present in the great majority of Mammals; but they are only present in the embryo of the Whalebone Whales, and are entirely absent in the genera *Echidna*, *Manis*, and *Myrmecophaga*. In the Duck-mole (*Ornithorhynchus*) the teeth are horny, and the same was the case in the extinct *Rhytina* amongst the *Sirenia*. In all other Mammals the teeth have their ordinary structure of dentine, enamel, and crusta petrosa, these elements being variously disposed in different cases. In no Mammals are the teeth ever anchylosed with the jaw, and in all the teeth are implanted into distinct sockets or alveoli, which, however, are very imperfect in some of the Cetacea.

Many Mammals have only a single set of teeth throughout life, and these are termed by Owen "monophyodont." In most cases, however, the first set of teeth—called the "milk" or "deciduous" teeth—is replaced in the course of growth by a second set of "permanent" teeth. The deciduous and permanent sets of teeth do not necessarily correspond to one another; but no Mammal has ever *more* than these two sets. The Mammals with two sets of teeth are called by Owen "diphyodont."

In Man and in many other Mammals the teeth are divisible into four distinct groups, which differ from one another in position, appearance, and function; and which are known

respectively as the *incisors*, *canines*, *præmolars*, and *molars* (fig. 335). "Those teeth which are implanted in the præmaxillary bones, and in the corresponding part of the lower jaw, are called 'incisors,' whatever be their shape or size. The tooth in the maxillary bone which is situated at or near to the suture with the præmaxillary, is the 'canine,' as is also that tooth in the lower jaw which, in opposing it, passes in front of its crown when the mouth is closed. The other teeth of the first set are the 'deciduous molars;' the teeth which displace and succeed them vertically are the 'præmolars;' the more posterior teeth, which are not displaced by vertical successors, are the 'molars' properly so called."—(Owen.) The deciduous dentition, therefore, of a diphyodont Mammal, consists of only three kinds of teeth—incisors, canines, and

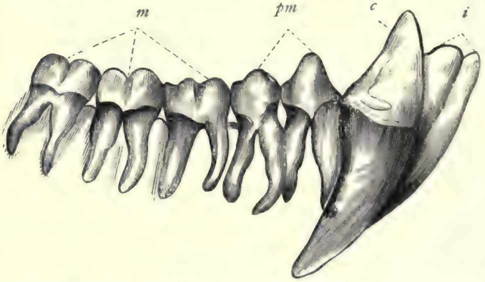


Fig. 335.—Teeth of the right side of the lower jaw of the Chimpanzee (after Owen). *i* Incisors; *c* Canine; *pm* Præmolars; *m* Molars.

molars. The incisor and canine teeth of the deciduous set are replaced by the teeth which bear the same names in the permanent set. The deciduous "molars," however, are replaced by the permanent "præmolars," and the "molars" of the permanent set of teeth are not represented in the deciduous series, only existing once, and not being replaced by successors.

All these four kinds of teeth are not necessarily present in all Mammals, and, as will be afterwards seen, the characters of the teeth are amongst the most important of the distinctions by which the Mammalian orders are separated from one another. The variations which exist in the number of teeth in different Mammals are usually expressed by a "dental formula," which presents the "dentition" of both jaws in a condensed and easily-recognised form.

According to Owen, the typical permanent dentition of a diphyodont Mammal would be expressed by the following formula :—

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{4-4}{4-4};\ m\,\frac{3-3}{3-3} = 44.$$

The four kinds of teeth are indicated in such a formula by the letters—incisors *i*, canines *c*, præmolars *pm*, molars *m*. The numbers in the upper line indicate the teeth in the upper jaw, those in the lower line stand for those in the lower jaw; and the number of teeth on each side of the jaw is indicated by the short dashes between the figures.

As regards their general *distribution in time*, as a matter of course, the remains of Mammals are scanty, and occupy but a small space in the geological record; since the greater number of the *Mammalia* are terrestrial, and the greater number of the stratified fossiliferous deposits are marine. The Mammals, too, are the most highly organised of the entire sub-kingdom of the *Vertebrata;* and therefore, in obedience to the well-known law of succession, they ought to make their appearance upon the globe at a later period than any of the lower classes of the *Vertebrata*. Such, in point of fact, is to a great extent the case; and if the geological record were perfect, the law would doubtless be carried out to its full extent.

It is in the upper portion of the Triassic Rocks—that is to say, not long after the commencement of the Mesozoic or Secondary epoch—that Mammals for the first time make their appearance; three or four species being now known in a zone of rocks which are placed at the summit of the Trias, just where this formation begins to pass into the Lias. The earliest of these —the oldest known of all the Mammals—appears at the upper part of the Upper Trias (Keuper) and also at its very summit (Penarth beds), and has been described under the name of *Microlestes antiquus*. The nearest ally of *Microlestes* amongst existing Mammals would seem to be the Marsupial and insectivorous *Myrmecobius*, or Banded Ant-eater of Australia. As only the teeth, however, of *Microlestes* have hitherto been discovered, it is impossible to decide positively whether this primeval Mammal was Marsupial or Placental.

The next traces of Mammals occur in the Stonesfield Slate (Lower Oolites), and here four species, all of small size, are known to occur. Most of these were Marsupial, but it is possible that one was Placental. They form the genera *Amphilestes*, *Amphitherium*, *Phascolotherium*, and *Stereognathus*. After the Stonesfield Slate another interval succeeds, in which no

Mammalian remains have hitherto been found ; but in the fresh-water formation of the Middle Purbeck, at the top, namely, of the Oolitic series, as many as fourteen small Mammals have been discovered. These constitute the genera *Plagiaulax*, *Spalacotherium*, *Triconodon*, and *Galestes*. Another gap then follows, no Mammal having hitherto been discovered in any portion of the Cretaceous series (with doubtful exceptions).

Leaving the Mesozoic and entering upon the Kainozoic period, remains of Mammals are never absent from any of the geological formations. From the base of the Eocene Rocks up to the present day remains of Mammals commonly occur, constantly increasing in number and importance, till we arrive at the fauna now in existence upon the globe.

In the following are given the characters of each order of the *Mammalia*, with the range in time, and, so far as known, the more important fossil forms of each. The number, however, of known fossil Mammals is so great, and in many cases they exhibit so many peculiarities and divergences from existing forms, that nothing more can be attempted here than to give a brief and general sketch of the palæontological history of the class ; attention being drawn, where it may seem necessary, to extinct types of special interest.

CHAPTER XXXVI.

ORDERS OF MAMMALIA.

ORDER I. MONOTREMATA.—The first and lowest order of the *Mammalia* is that of the *Monotremata*, containing only two genera, both belonging to Australia—namely, the Duck-mole (*Ornithorhynchus*) and the Porcupine Ant-eater (*Echidna*).

The order is distinguished by the following characters :—The intestine opens into a "cloaca," which receives also the products of the urinary and generative organs, which discharge themselves into a urogenital canal—the condition of parts being very much the same as in Birds. The jaws are either wholly destitute of teeth (*Echidna*), or are furnished with horny plates which act as teeth. The pectoral arch has some highly bird-like characters, the most important of these being the extension of the coracoid bones to the anterior end of the sternum. The females possess no marsupial pouch, but the pelvis is furnished with the so-called "marsupial bones," be-

lieved to be ossifications of the internal tendon of the external oblique muscle of the abdomen. The corpus callosum is very small, and has been asserted to be altogether wanting. There are no external ears. The mammary glands have no nipples, and their ducts open either into a kind of integumentary pouch (*Echidna*) or simply on a flat surface (*Ornithorhynchus*). The young are said to be destitute of a placenta, or, in other words, no vascular connection is established between the fœtus and the mother. The feet have five toes each, armed with claws, and the males carry perforated spurs on the back of the tarsus (attached to a supplementary tarsal bone).

As regards their geological history, the Monotremes are not known to be represented at all in past time; and this need not excite any surprise, seeing that the order is represented at the present day by no more than two genera, both confined to a single geographical region. Upon theoretical grounds, however, it may be expected that we shall ultimately discover that the antiquity of the order *Monotremata* is extremely high.

ORDER II. MARSUPIALIA.—The order *Marsupialia* forms with the *Monotremata* the division of the Non-placental Mammals. With the single exception of the genus *Didelphys*, which is American, all the *Marsupialia* belong to the Melanesian province; that is to say, they all belong to Australia, Van Diemen's Land, New Guinea, and some of the neighbouring islands.

The following are the characters which distinguish the order:—

The skull is composed of distinct cranial bones united by sutures, and they all possess true teeth; whilst the angle of the lower jaw is almost always inflected. The pectoral arch has the same form as in the higher Mammals, and the coracoid no longer reaches the anterior end of the sternum. All possess the so-called "marsupial bones" (fig. 336), attached to the brim of the pelvis. The corpus callosum is very small, and has been asserted to be absent. The young Marsupials are born in a very imperfect condition, of very small size, and at a stage when their development has proceeded to a very limited degree only. It is believed that there is no placenta or vascular communication between the mother and fœtus, parturition taking place before any necessity arises for such an arrangement. As the young are born in such an imperfect state of development, special arrangements are required to secure their existence. When born, they are therefore, in the great majority of cases, transferred by the mother to a peculiar pouch formed by a folding of the integument of the abdomen. This pouch is known as the "marsupium," and gives the name

to the order. Within the marsupium are contained the nipples, which are of great length. Being for some time after their birth extremely feeble, and unable to perform the act of suction, the young within the pouch are nourished involuntarily, the mammary glands being provided with special muscles which force the milk into the mouths of the young. At a later stage the young can suckle by their own exertions, and they leave the pouch and return to it at will. In a few forms there is no complete marsupium as above described; but the structure of the nipples is the same, and the young are carried about by the mother, adhering to the lengthy teats.

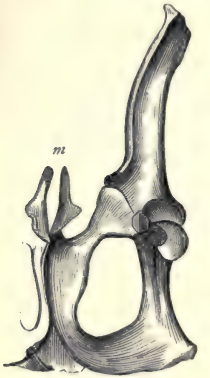


Fig. 336.—One side of the pelvis of a Kangaroo, showing the "marsupial bones" (*m*). After Owen.

The so-called "marsupial bones" (fig. 336) doubtless serve to support the marsupial pouch and its contained young, but this cannot be their sole function, since they occur in the Monotremes, in which there is no pouch.

They consist of two small bones, which spring from the brim of the pelvis, and which are merely ossifications of the internal tendons of the "external oblique" muscles of the abdomen.

The *Marsupialia* may be primarily divided into the vegetable-eating and the rapacious or carnivorous forms—the former characterised by the rudimentary condition or absence of the canine teeth, the molars mostly having broad grinding crowns; whilst in the latter there are well-developed canines, and the molars mostly have trenchant edges. In the phytophagous section are the living Kangaroos (*Macropodidæ*), the Wombat (*Phascolomys*), the Kangaroo-rats (*Hypsiprymnus*), and the Phalangers (*Phalangistidæ*). In the carnivorous section are the true Opossums (*Didelphidæ*), the Banded Ant-eater (*Myrmecobius*), the *Thylacinus*, and the "native devil" or *Dasyurus*.

As regards their distribution in time, the *Marsupialia* probably constitute the oldest of the Mammalian orders. Owing, however, to the detached and fragmentary condition of almost all Mammalian remains—consisting in many cases of the ramus of the lower jaw, or of separate teeth—it is not possible

to state this with absolute certainty. The oldest known European Mammal is the *Microlestes antiquus* of the Upper Trias, only a few teeth of which have been as yet detected. The earliest horizon on which *Microlestes* occurs is in a "bone-bed" in the Keuper of Würtemberg; but it has also been detected in the higher "Rhætic" beds. Professor Owen believes that the *Hypsiprymnopsis* of Mr Boyd Dawkins, from the Rhætic marls of Somersetshire, is also referable to *Microlestes*. Upon the whole, it is most probable that *Microlestes* was Marsupial; and it appears to be most nearly related to the little insectivorous *Myrmecobius* or Banded Ant-eater of New South Wales (fig. 337).

Fig. 337.—*Myrmecobius fasciatus*.

Nearly allied to *Microlestes* is a small Mammal, a lower jaw of which has been obtained from the Trias of North America, and which has been described under the name of *Dromatherium sylvestre*. This little animal (fig. 338) appears also to be Marsupial, and to be most nearly related to *Myrmecobius*. Each

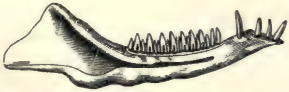


Fig. 338.—Lower jaw of *Dromatherium sylvestre* (after Emmons). From rocks supposed to be of Triassic age, in North Carolina.

ramus of the lower jaw contains "ten small molars in a continuous series, one canine, and three conical incisors—the latter being divided by short intervals" (Owen).

The next Mammaliferous horizon above the Trias is the Stonesfield Slate in the Lower Oolites; and there is no doubt that some, if not all, of the Mammalian remains of this belong to small Marsupials. Four genera of small Mammals are known from this horizon — viz., *Amphilestes*, *Amphitherium*, *Phascolotherium*, and *Stereognathus*. In *Amphitherium* (fig. 339), the molars are cuspidate, and the animal was doubtless

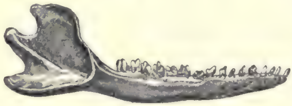


Fig. 339.—Ramus of the lower jaw of *Amphitherium* (*Thylacotherium*) *Prevostii*. Stonesfield Slate.

insectivorous. It is believed by Owen to be Marsupial, and to be most nearly related to *Myrmecobius*. *Amphilestes* and *Phascolotherium* (fig. 340) are also believed by the same high authority to have been insectivorous Marsupials, and the latter is supposed to find its nearest living ally in the Opossums of America. Lastly, the *Stereognathus* of the Stonesfield Slate is in a dubious position. It may have been Marsupial; but, upon the whole, Professor Owen is inclined to believe that it was placental, hoofed, and herbivorous.

With the occurrence of small Marsupials in England within the Oolitic period, it is interesting to notice how the fauna of that time approached in other respects to that now inhabiting Australia. At the present day, Australia is almost wholly tenanted by Marsupials; upon its land-surface flourish *Araucariæ* and Cycadaceous plants, and in its seas swims the Port-Jackson Shark (*Cestracion Philippi*); whilst the Molluscan genus *Trigonia* is nowadays exclusively confined to the Australian coasts. In England at the time of the deposition of the Stonesfield Slate, we must have had a fauna and flora very closely resembling what we now see in Australia. The small Marsupials *Amphitherium* and *Phascolotherium* prove that the Mammals were the same in order; cones of Araucarian pines, with tree-ferns and fronds of Cycads, occur throughout the Oolitic series; spine-bearing fishes, like the Port-Jackson Shark, are abundantly represented by genera such as *Acrodus* and *Strophodus;* and lastly, the genus *Trigonia*, now exclusively Australian, is represented in the Stonesfield Slate by species which differ little from those now existing.

Another singular point of resemblance is established by the

occurrence in the rivers of Queensland of the "Barramunda," which is referred to the genus *Ceratodus*—a genus which, though pre-eminently Triassic, nevertheless extended its range into the Jurassic period.

Towards the close of the Oolitic period, in the Middle Purbeck beds, we have evidence of a number of small Mammals, all of which are probably referable to the *Marsupialia*. Fourteen species are known, all of small size, the largest being no bigger than a polecat or hedgehog. The genera to which these little quadrupeds have been referred are *Plagiaulax*, *Spalacotherium*, *Triconodon*, and *Galestes*. The first of these—viz., *Plagiaulax* (fig. 340, 4)—is believed to be most nearly allied to the living

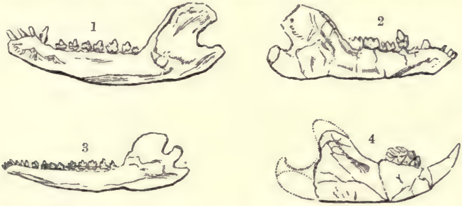


Fig. 340.—Oolitic Mammals, natural size. 1. Lower jaw and teeth of *Phascolotherium*; 2. of *Triconodon*; 3. of *Amphitherium*; 4. of *Plagiaulax*.

Kangaroo-rats (*Hypsiprymnus*) of Australia; and it is held by good authorities to have been phytophagous, as are its living relatives. Professor Owen, on the other hand, maintains that *Plagiaulax* was carnivorous. The remaining three genera—viz., *Spalacotherium*, *Triconodon* (fig. 340, 2), and *Galestes*—appear to have been certainly insectivorous, and find their nearest living allies in the Australian Phalangers and the American Opossums.

In the older Tertiary Rocks the remains of Marsupials are not abundant. In the Eocene Tertiary (Gypseous series of Montmartre), however, occurs an Opossum, which is very closely allied to the existing American forms, and which has been named the *Didelphys Gypsorum*. Other species of the same genus have also been discovered in deposits of Miocene age.

In the later Tertiary and Post-tertiary period the order of the *Marsupialia* is represented by some very remarkable forms. The remains in question have been found in the bone-caves of Australia—the country in which Marsupials now abound above every other part of the globe; and they show that Australia,

at no distant geological period, possessed a Marsupial fauna, much resembling that which it has at present, but comparatively of a much more gigantic size. In the remains from the Australian bone-caves, almost all the most characteristic living Marsupials of Australia and Van Diemen's Land are represented ; but the extinct forms are usually of much greater size. We have Wombats, Phalangers, Flying Phalangers, and Kangaroos, with carnivorous Marsupials resembling the recent *Thylacinus* and *Dasyurus*. The two most remarkable of these extinct forms are *Diprotodon* and *Thylacoleo*. In most essential respects *Diprotodon* resembled the Kangaroos, the dentition, especially, showing many points of affinity. The hind-limbs, however, of *Diprotodon* were by no means so disproportionately long as in the Kangaroos. In size, *Diprotodon* must have many times exceeded the largest of the living Kangaroos, since the skull measures three feet in length (fig. 341).

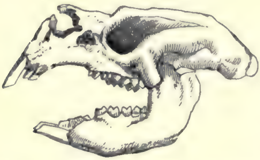


Fig. 341.—Skull of *Diprotodon Australis*.

Smaller than *Diprotodon* is *Nototherium*, a genus which is also most nearly allied to the living Kangaroos.

Thylacoleo (fig. 342), like *Plagiaulax*, is in a disputed posi-

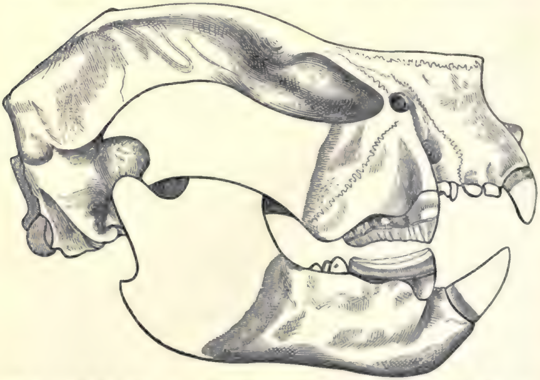


Fig. 342.—Skull of *Thylacoleo*. Post-Tertiary deposits of Australia. (After Flower.)

tion. By Professor Owen it is regarded as being strictly carnivorous, and as finding its nearest living ally in the Thylacine. The great feature in the dentition is the presence in either jaw of one huge, compressed, and trenchant præmolar. This is regarded by Owen as a "carnassial;" but Professor Flower, with greater probability, regards it as corresponding to the great cutting præmolar of the Kangaroo-rats (*Hypsiprymnus*), a view which is further borne out by the small size of the canines in *Thylacoleo*. Upon the whole, therefore, Flower concludes that "*Thylacoleo* is a highly-modified and aberrant form of the type of Marsupials now represented by the *Macropodidæ* and *Phalangistidæ*, though not belonging to either of these families as now restricted," and he believes that its diet was of a vegetable nature. Under any view of its habits, *Thylacoleo* is a very remarkable type of the Marsupials; and it must have attained a very great size, since the length of the crown of the great præmolar is not less than two inches and a quarter.

ORDER III. EDENTATA, or BRUTA.—The lowest order of the placental or monodelphous Mammals is that of the *Edentata*, often known by the name of *Bruta*. The name *Edentata* is certainly not an altogether appropriate one, since it is only in two genera in the order that there are absolutely no teeth. The remaining members of the order have teeth, but these are always destitute of true enamel, are never displaced by a second set, and have no complete roots. Further, in none of the *Edentata* are there any median incisors, and in only one species (one of the Armadillos) are there any incisor teeth at all. Canine teeth, too, are almost invariably wanting. Clavicles are usually present, but are absent in the Scaly Anteater (*Manis*). All the toes are furnished with long and powerful claws. The mammary glands are usually pectoral, but are sometimes abdominal in position. The testes are abdominal in position. The skin is often covered with bony plates or horny scales.

The order *Edentata* is conveniently divided into two great sections, in accordance with the nature of the food, the one section being phytophagous, the other insectivorous. In the former section is the single group of the Sloths (*Bradypodidæ*). In the latter are the two groups of the Armadillos (*Dasypodidæ*), and the various species of Ant-eaters (the latter constituting Owen's group of the *Edentula*).

The Edentates, like the Marsupials, are singularly circumscribed at the present day. No member of the order is at the present time indigenous in Europe. Tropical Asia and Africa

have the Scaly Ant-eaters or Pangolins; and in Africa occurs the Edentate genus *Orycteropus*. South America, however, is the metropolis of the *Edentata*, the order being there represented by the Sloths, the Armadillos, and the true Ant-eaters. It is also in South America that by far the greater number of extinct Edentates have been found; and, as in the case of the Australian Marsupials, the fossil forms are gigantic in size as compared with their living representatives.

The oldest known representative of the *Edentata* is the *Macrotherium* of the Miocene Tertiary of France. This is a gigantic Edentate, intermediate in some respects between the Pangolins (*Manis*) and the Aardwark (*Orycteropus*). There does not appear to have been any dermal armour, and the teeth are rootless and destitute of enamel. The ungual phalanges are bent like those of the Pangolins, and the animal doubtless possessed long curved claws. From the Upper Miocene of Attica, M. Gaudry has also described a gigantic Edentate, allied to *Macrotherium*, and larger than a Rhinoceros. The name assigned to this singular form is *Ancylotherium Pentelici*.

In comparatively recent deposits in South America are found remains of Edentates corresponding to the three groups which now inhabit that continent—viz., the Sloths, Armadillos, and Hairy Ant-eaters. The Sloths (*Bradypodidæ*) are represented in the Post-tertiary deposits of South America by a group of gigantic forms, the most important of which belong to the genera *Megatherium*, *Mylodon*, and *Megalonyx*.

Megatherium (fig. 343) was a colossal Sloth-like Edentate,

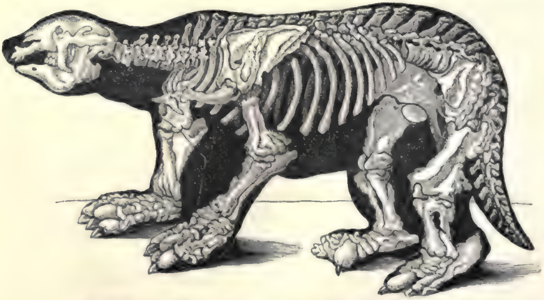


Fig. 343.—*Megatherium Cuvieri*. Post-Pliocene, South America.

which attained a length of eighteen feet, with bones as massive as, or more so than, those of the Elephant. The jaws are destitute of canine and incisor teeth, but there are five upper and four lower molars on each side. All the molars have the form of quadrangular prisms, the crowns of which are furnished with well-marked transverse ridges: and they grew from permanent pulps. The limbs are extremely massive, and the pectoral arch has a clavicle. The digits are very large and strong, and some of them are furnished with well-developed claws. The tail is enormously thick. Unlike the living Sloths, *Megatherium* must have been terrestrial in its habits, and must have lived upon the foliage of trees which it uprooted for itself.

The genus *Mylodon* comprises large Sloth-like animals, of which the best known is the *Mylodon robustus* (fig. 344). In its size, *Mylodon robustus* was smaller than the *Megatherium*, but it reached a length of eleven feet. In many respects

Fig. 344.—Skeleton of *Mylodon robustus*. Post-Pliocene, South America.

Mylodon is very like *Megatherium*, and the number of the teeth is the same—viz., five upper and four lower molars on each side. The crowns of the molars, however, were flat, instead of being ridged. The fore-feet are pentadacty-

lous, and the posterior tetradactylous, the two external digits being nailless.

Megalonyx, unlike the preceding, has been found in both North and South America. It has the same number of teeth as *Megatherium* and *Mylodon*, but the crowns of these are excavated centrally and have a prominent margin. The fore-limbs are shorter than the hind-limbs, and the calcaneum is unusually long. *Megalonyx* was probably about the size of an ox.

Just as the Sloths of the present day were formerly represented in the same geographical area by the gigantic Megatheroids, so the little banded and cuirassed Armadillos of South America were formerly represented by gigantic species, constituting the genus *Glyptodon*. The *Glyptodons* (fig. 345) differed from the living Armadillos in having no bands in their armour, so that they must have been unable to roll themselves up. It is rare at the present day to meet with any Armadillo over two or three feet in length; but the length of the *Glyptodon clavipes*, from the tip of the snout to the end of the tail, was more than nine feet.

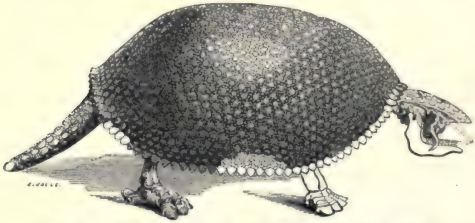


Fig. 345.—*Glyptodon clavipes*. Post Pliocene, South America.

There are no canine or incisor teeth in the *Glyptodon*, but there are eight molars on each side of each jaw, and the crowns of these are fluted and almost trilobed. The head is covered by a helmet of bony plates, and the trunk was defended by an armour of almost hexagonal bony pieces united by sutures, and exhibiting special patterns of sculpturing in each species. The tail was also defended by a similar armour, and the vertebræ were mostly fused together so as to form a cylindrical bony rod. The feet are massive, and the ungual phalanges short and compressed.

Besides the various species of *Glyptodon*, South America has also yielded the remains of several true species of *Dasypus*, nearly allied to the living Armadillos. These have been found

in the ossiferous caverns of Brazil; in which occur also other Edentates, which have been referred to separate genera, but the affinities of which are somewhat dubious.

CHAPTER XXXVII.

ORDERS OF MAMMALIA—Continued.

Order IV. Sirenia.—This order comprises no other living animals except the Dugongs and Manatees, which are often placed with the true *Cetaceans* (Whales and Dolphins) in a common order. There is no doubt, in fact, but that the *Sirenia* are very closely allied to the *Cetacea*, and though they are to be regarded as separate orders, yet they may be advantageously considered as belonging to a single section, which has been called *Mutilata*, from the constant absence of the hind-limbs.

The *Sirenia* agree with the Whales and Dolphins in their complete adaptation to an aquatic mode of life (fig. 346); especially in the presence of a powerful caudal fin, which differs from that of Fishes in being placed horizontally and in being a mere expansion of the integuments, not supported by bony rays. The hind-limbs are wholly wanting, and there is no sacrum. The anterior limbs are converted into swimming-paddles or "flippers." The snout is fleshy and well developed, and the nostrils are placed on its upper surface, and not on the top of the head, as in the Whales. Fleshy lips are present, and the upper one usually carries a moustache. The skin is covered with fleshy bristles. The head is not disproportionately large, as in the true Whales, and is not so gradually prolonged into the body as it is in the latter. There may be only six cervical vertebræ. The teats are two in number and are "thoracic," —*i. e.*, are placed on the chest. There are no clavicles, and the digits have no more than three phalanges each. The testes are retained throughout life within the abdomen, but vesiculæ seminales are present. The animal is diphyodont, the permanent teeth consisting of molars with flattened crowns adapted for bruising vegetable food, and incisors, which are present in the young animal, at any rate. In the extinct *Rhytina* it does not appear that there were any incisor teeth.

The only existing *Sirenia* are the Manatees (*Manatus*) and

the Dugongs (*Halicore*), often spoken of collectively as "sea-cows," and forming the family of the *Manatidæ*.

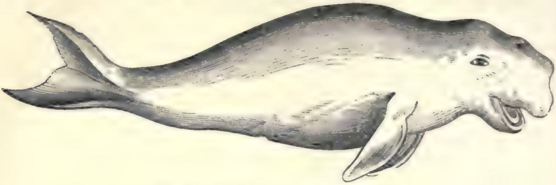


Fig. 346.—Sirenia. Dugong (*Halicore*).

The most important, if not the only, fossil remains which can be referred with certainty to the *Sirenia*, are those upon which the genus *Halitherium* has been founded. The upper incisors in this genus are tusk-like, the lower incisors small, and the molars furnished with tubercular crowns. *Halitherium* appears to be in some respects intermediate between the Dugongs and Manatees; and several species of the genus are known, ranging from the Eocene to the Pliocene Tertiary.

The genus *Deinotherium* referred to this order by De Blainville, and still retained in this position by Pictet, will be here considered as belonging to the order of the *Proboscidea*.

ORDER V. CETACEA.—In this order are the Whales, Dolphins, and Porpoises, all agreeing with the preceding in their complete adaptation to an aquatic life. The body is completely fish-like in form; the anterior limbs are converted into swimming-paddles or "flippers;" the proximal bones of the fore-limbs are much reduced in length, and the succeeding bones are shortened and flattened, and are enveloped in a tendinous skin, thus reducing the limbs to oar-like fins; there are no external ears; the posterior limbs are completely absent; and there is a powerful, horizontally-flattened, caudal fin, sometimes accompanied by a dorsal fin as well. In all these characters the *Cetacea* agree with the *Sirenia*, except in the one last mentioned. On the other hand, the nostrils, which may be single or double, are always placed at the top of the head, constituting the so-called "blow-holes" or "spiracles;" and they are never situated at the end of a snout. The body is very sparingly furnished with hairs, or the adult may be completely hairless. The teats are two in number and are placed upon the groin. The head is generally of disproportionately large size, and is never separated from the body by any distinct constriction or neck. The lumbar region of the spine is long,

and, as in the *Sirenia*, there is no sacrum, and the pelvis is only present in a rudimentary form. There are no clavicles, and some of the digits may possess more than three phalanges each. Lastly, the adult is either destitute of teeth or, with exception of the Zeuglodonts, is monophyodont—that is to say, possesses but a single set of teeth, which are never replaced by others. When teeth are present, they are usually conical and numerous, and they are almost always of one kind only.

The *Cetacea* may be divided into the two sections of the *Balænidæ*, comprising only the "Whalebone Whales," in which true teeth are absent; and the "Toothed Whales" or *Odontoceti*, comprising the living families of the *Delphinidæ* (Dolphins and Porpoises), the *Catodontidæ* (Sperm Whales), and the *Rhynchoceti* ("Ziphioid" Whales), with the extinct family of the *Zeuglodontidæ*.

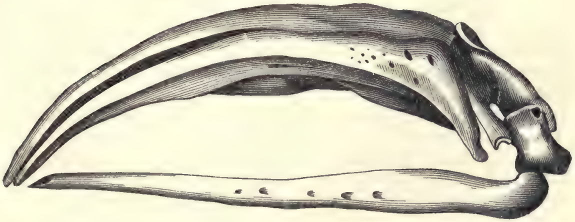


Fig. 347.—Skull of the Right Whale (*Balæna mysticetus*)—after Owen.

Fam. 1. *Balænidæ*.—The *Balænidæ* or Toothless Whales are characterised by the total absence of teeth in the adult (fig. 347). Teeth, however, are present in the fœtal Whale, but they never cut the gum. The place of teeth is supplied by a number of plates of whalebone or "baleen" attached to the palate; hence the name of "Whalebone Whales" often given to this family. They are the largest of living animals, and may be divided into the two sections of the *Smooth* Whales, in which the skin is smooth, and there is no dorsal fin (as in the Greenland Whale), and the *Furrowed* Whales, in which the skin is furrowed, and a dorsal fin is present (as in the so-called Finner Whales and Hump-backed Whales).

The *Balænidæ* are of little geological importance. In Pliocene deposits have been found remains referred to the Rorquals; and bones of the Whalebone Whales have also been found in various Post-Tertiary accumulations. It is probable, like-

wise, that the ear-bones or "cetotolites" which occur in the Red Crag (Pliocene) are, in some instances at any rate, referable to members of the *Balænidæ*.

Fam. 2. *Catodontidæ*.—The family of the *Catodontidæ*, or *Physeteridæ*, comprises the Sperm Whales or Cachalots, with which we commence the series of the Toothed Whales (*Odontoceti*). They are characterised by the fact that the palate is destitute of baleen plates, and the lower jaw possesses a series (about fifty-four) of pointed conical teeth, separated by intervals, and sunk in a common alveolar groove, which is only imperfectly divided by septa. The upper jaw is also in reality furnished with teeth—but, with a single partial exception, these do not cut the gum.

Remains of Cachalots (*Physeter*) occur in the Pliocene and Post-Tertiary deposits, and their existence has even been indicated in the Miocene Tertiary. They are, however, of no special importance.

Fam. 3. *Delphinidæ*.—This family includes the Dolphins, Porpoises, and Narwhal, and is characterised by usually possessing teeth in both jaws; the teeth being numerous, and conical in shape. The nostrils, as in the last family, are united, but they are placed further back, upon the top of the head. The single blow-hole or nostril is transverse and mostly crescentic or lunate in shape. The head is by no means so disproportionately large as in the former families, usually forming about one-seventh of the entire length of the body.

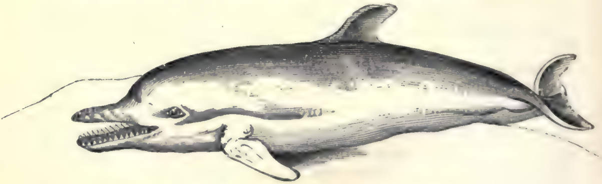


Fig. 348.—The common Dolphin (*Delphinus delphis*).

The genus *Delphinus*, comprising the common Dolphins, appears to date from the Miocene Tertiary, and is well represented in deposits of Pliocene age. In Miocene strata also occur the Delphinoid remains which have been referred to the genera *Stereodelphis* and *Champsodelphis*.

Fam. 4. *Rhynchoceti*.—This family is allied to the Cachalots or Sperm Whales, and includes the so-called "Ziphioid Whales." They are distinguished by the possession of a

pointed snout (the "beak" or "rostrum"), single blow-hole, and small dorsal fin; and by their dentition. The upper jaw is edentulous, any teeth which may be present not cutting the gum. The lower jaw, on the other hand, possesses usually a single pair of teeth, which are sometimes tusk-like, but which in other cases are concealed by the gum.

The rostrum of these Cetaceans is of great density, and has often been preserved in a fossil state, usually presenting itself as a bony cylinder or elongated cone, generally more or less water-worn. Upon fossils of this nature have been founded the genera *Choneziphius* and *Belemnoziphius*, both of which occur in the so-called "Crags" (Pliocene). The genus *Ziphius* also occurs in the Crag, but unlike the preceding it is represented by existing species. Besides the "beaks," some fossil teeth have been found, which may perhaps be referable to members of this family.

Fam. 5. *Zeuglodontidæ.*—The members of this family differ from all existing *Odontoceti* in the possession of molar teeth implanted by two distinct fangs. The Zeuglodonts are entirely extinct, and they are exclusively confined to the Eocene, Miocene, and Pliocene periods. The chief genera are *Zeuglodon* and *Squalodon.*

Zeuglodon (fig. 349) is distinguished by its elongated snout, conical incisors, and molar teeth with triangular serrated crowns, implanted in the jaw by two roots. Each molar looks

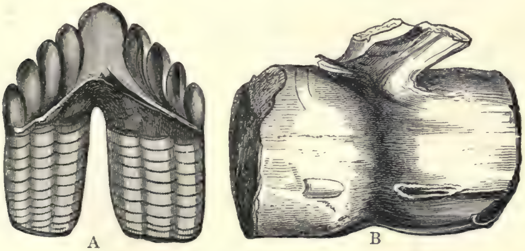


Fig. 349.—*Zeuglodon cetoides.* A, Molar tooth, natural size; B, Vertebra, reduced. From the Middle Eocene of North America. (After Lyell.)

as if it were composed of two separate teeth united on one side by their crowns; and it is this peculiarity which is expressed by the generic name. The species of *Zeuglodon* are Eocene and Miocene, one of the best known being the great *Z.*

cetoides of the Middle Eocene (Jackson Beds) of the United States, which attained a length of seventy feet.

By Professor Huxley, *Zeuglodon* is regarded as intermediate between the true Cetaceans and the Carnivorous family of the Seals. On this point, this eminent naturalist remarks :—"The skull of this great Eocene sea-monster, in fact, shows, by the narrow and prolonged interorbital region ; the extensive union of the parietal bones in a sagittal suture ; the well-developed nasal bones ; the distinct and large incisors implanted in præmaxillary bones, which take a full share in bounding the fore-part of the gape ; the two-fanged molar teeth with triangular and serrated crowns, not exceeding five on each side in each jaw ; and the existence of a deciduous dentition,—its close relation with the Seals. While, on the other hand, the produced rostral form of the snout, the long symphysis, and the low coronary process of the mandible, are approximations to the Cetacean form of those parts."

The genus *Squalodon* is nearly related to *Zeuglodon*, but the teeth are more numerous ; and the double-fanged molars are more compressed and pyramidal in form. "The nasal bones are very short, and the upper surface of the rostrum presents the groove, filled up during life by the prolongation of the ethmoidal cartilage, which is so characteristic of the majority of Cetaceans" (Huxley). The species of *Squalodon* all belong to the Miocene and Pliocene Tertiary.

The genus *Saurocetes* has been founded for the reception of another Zeuglodont, in which there were double-fanged teeth with conoid crowns. The remains on which this genus are based, are from strata of Tertiary age, near Buenos Ayres, and they indicate an animal much smaller than the true *Zeuglodons*.

Lastly, it would appear probable that the genus *Balænodon*, founded upon teeth from the Red Crag (Pliocene), is really referable to this family, and probably to the genus *Squalodon*. In part, however, teeth of Ziphioid Whales have also been included under this title. By Owen *Balænodon* is regarded as comprising teeth of a Cetacean nearly allied to the living Sperm Whale.

CHAPTER XXXVIII.

ORDERS OF MAMMALIA—Continued.

ORDER VI. UNGULATA.—The order of the *Ungulata*, or Hoofed Quadrupeds, is one of the largest and most important of all the divisions of the *Mammalia*. It comprises three entire old orders—namely, the *Pachydermata*, *Solidungula*, and *Ruminantia*.

The first of these old divisions—that of the *Pachydermata*—included the Elephants, Rhinoceros, Hippopotamus, Tapirs, and the Pigs, all characterised, as the name implies, by their thick integuments. The name is still used to express this fact, though the order is now abandoned, and is merged with that of the *Ungulata;* the Elephants alone being removed to a separate order under the name of *Proboscidea.*

The second old order—that of the *Solidungula* or Solipedes—included the Horse, Zebra, and Ass, all characterised by the fact that the foot terminates in a single toe, encased in an expanded hoof. The name *Solidungula* is still retained for these animals, as a section of the *Ungulata.*

The third old order—that of the *Ruminantia*—includes all those animals, such as Oxen, Sheep, Goats, Camels, Giraffes, Deer, and others, which chew the cud or "ruminate," and have two functional toes to each foot, encased in hoofs. The name *Ruminantia* is still retained for these animals, as constituting a most natural group of the *Ungulata.*

All these various animals, then, are now grouped together into the single order of the *Ungulata*, or Hoofed Quadrupeds, and the following are the characters of the order:—

All the four limbs are present, and that portion of the toe which touches the ground is always encased in a greatly-expanded nail, constituting a "hoof." There are never more than *four* full-sized toes to each limb. Owing to the encasement of the toes in hoofs, the limbs are useless for prehension, and only subserve locomotion; hence *clavicles* are always wanting in the entire order. There are always two sets of enamelled teeth, so that the animal is diphyodont. The molar teeth are massive and have broad crowns, adapted for grinding vegetable substances.

The order *Ungulata* is divided into two primary sections:—the *Perissodactyla*, in which the toes or hoofs are odd in number (one or three), and the *Artiodactyla*, in which the toes are even in number (two or four).

SECTION A. PERISSODACTYLA.—The section of the *Perissodactyle* Ungulates includes the Rhinoceros, the Tapirs, the Horse and its allies, and some extinct forms, all agreeing in the following characters:—

The hind-feet are odd-toed in all, and the fore-feet in all except the Tapirs. The dorso-lumbar vertebræ are never less than twenty-two in number. The femur has a third trochanter. The horns, if present, are not paired. Usually there is only one horn, but if there are two, these are placed in the middle line of the head, one behind the other. In neither case are the horns ever supported by bony horn-cores. The stomach is simple, and is not divided into several compartments; and there is a large and capacious cæcum.

The three existing genera of Perissodactyle Ungulates—namely, the Horse, Tapir, and Rhinoceros, are widely removed from one another in many important characters; but the intervals between them are filled up by an extensive series of fossil forms, commencing in the Lower Tertiary Strata.

Fam. 1. *Rhinocerida.*—This family comprises only a single genus, the genus *Rhinoceros.* The Rhinoceroses are extremely large and bulky brutes, having a very thick skin, which is usually thrown into deep folds. The muzzle is rounded and blunt, and there are $\frac{7-7}{7-7}$ molars, with tuberculate crowns. There are no canines, but there are usually incisor teeth in both jaws. The skull is pyramidal, and the nasal bones are enormously developed. The feet are furnished with three toes each, encased in hoofs. The nasal bones usually support one or two horns, which are not paired. The horn is composed of longitudinal fibres, which are agglutinated together, and are of the nature of epidermic growths, somewhat analogous to hairs. When two horns are present, the hinder one is carried by the frontal bones, and is placed in the middle line of the head behind the anterior horn. The posterior horn is usually much shorter than the anterior one, and if not, it differs in shape. The Rhinoceroses live in marshy places, and subsist chiefly on the foliage of trees. They are exclusively confined at the present day to the warmer parts of the Old World; but an extinct species (*Rhinoceros tichorhinus*) formerly inhabited England, and ranged over the greater part of Europe.

The fossil species of Rhinoceros are numerous, commencing in the Miocene Tertiary, and ranging through the Pliocene and Post-Pliocene deposits. The species of Rhinoceros may be divided into groups, as follows:—

1. Those in which the nostrils are separated by a bony sep-

tum ("cloison"), and the incisor teeth are wanting in the adult (*R. tichorhinus*).

2. Those in which there is no bony partition between the nostrils, and the incisors are of medium size (*Rhinoceros megarhinus*).

3. Those in which there is no "cloison," and the incisors are of large size (*Rhinoceros incisivus*).

4. Those in which there is an imperfect bony partition between the nostrils (*Rhinoceros Etruscus* and *R. hemitœchus*).

The most important extinct forms of the genus *Rhinoceros* are the *R. tichorhinus*, *R. megarhinus*, *R. hemitœchus* (= *R. leptorhinus*, Owen), *R. Etruscus*, and the hornless species constituting the sub-genus *Acerotherium*.

The *Rhinoceros tichorhinus* is generally known as the "Woolly Rhinoceros," from its possession of a woolly covering. Its skin was foldless, and it possessed two horns, of which the anterior one was very large. The limbs are extremely stout, and the nostrils are completely separated by an osseous septum. *R. tichorhinus* is essentially a northern form, and has the same distribution *in space* as the Mammoth, except that it did not cross Behring Straits, and is therefore not found in America. In *time*, it is younger than the Mammoth, not being found in the præ-glacial forest-bed of Norfolk, and occurring for the first time in the Lower Brick-earths of the Thames valley (præ-glacial, but younger than the "forest-bed"). It is, therefore, essentially a Post-glacial Mammal, and it is mainly found in quaternary cave-deposits and valley-gravels. A molar tooth of this well-known form is figured below (fig. 351).

Fig. 350.—Penultimate molar of the lower jaw of *Rhinoceros megarhinus*, two-thirds of the natural size. Post-Pliocene.

Fig. 351.—Penultimate molar of the lower jaw of *Rhinoceros tichorhinus*, two-thirds of the natural size. Post-Pliocene.

The *Rhinoceros hemitœchus* of Falconer (= the *R. leptorhinus* of Owen) is also provided with two horns, but is of a much

more slender build than the Tichorhine form. The nasal bones are slender, and the nostrils are separated by a partially-ossified septum. The adult animal possesses neither incisor nor canine teeth. Like the preceding, *R. hemitæchus* is exclusively Post-Pliocene in its distribution, and is found in cave-deposits and in the Thames-valley Brick-earths.

The *Rhinoceros megarhinus* of Christol (= the *R. leptorhinus* of Cuvier and Falconer) is also bicorn, and resembles *R. hemitæchus* in being of comparatively slender build. It is distinguished, however, by the enormous development of the nasal bones and the absence of the "cloison" or bony partition between the nostrils. This form (fig. 350) is found in the Pliocene beds of Italy and France, and also occurs in the præ-glacial forest-bed of Cromer and the Lower Brick-earths of the Thames valley.

Rhinoceros Etruscus is also bicorn, and has the nostrils partially separated by a "demi-cloison" or incomplete bony partition, which "strengthened the basement of the anterior horn." This species is found in deposits of Pliocene age, and occurs also in the Post-Pliocene (as in the Cromer forest-bed).

In the Miocene period occur various remains of hornless species of Rhinoceros, which have often been united into a separate genus, or sub-genus, under the name of *Acerotherium*. Some of these forms have all the feet three-toed, and they constitute the *Rhinoceros incisivus* of Cuvier. The typical species of *Acerotherium*, on the other hand, are stated to agree with the living Tapirs in having the fore-feet four-toed.

Fam. 2. *Tapiridæ.*—The Tapirs are characterised by the possession of a short movable proboscis or trunk. The skull is pyramidal, and the nasal bones project over the nasal cavity. The skin is hairy and very thick. The tail is extremely short. The fore-feet have *four* toes each, but these are unsymmetrical, and the hind-feet have only three toes, all encased in hoofs. The jaws are furnished with incisor teeth, $(\frac{3-3}{3-3})$, small canines, and $\frac{7-7}{6-6}$ molars.

The genus *Tapirus*, including the existing Tapirs, appears for the first time in deposits of Miocene age, and is represented by various species in Pliocene and Post-Pliocene strata. The genus *Lophiodon* comprises Tapiroid Ungulates, which are essentially, if not exclusively, of Miocene age. They differ from the Tapirs almost solely in the characters of some of the molar and præmolar teeth. Lastly, the genus *Coryphodon*, likewise nearly related to the Tapirs, is found exclusively in the Eocene Tertiary.

Fam. 3. *Palæotheridæ.* — This family includes certain extinct Ungulates from the Eocene and Miocene Tertiary. They are characterised by the possession of three toes to all the feet, by having canines, and by the fact that the lower molars have a doubly crescentic form. The canines are longer than the other teeth, and the dental formula is—

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{4-4}{4-4};\ m\,\frac{3-3}{3-3} = 44.$$

The chief, if not the only, genus in this family is *Palæotherium* itself. Several species of this genus are known, varying in size from a sheep up to a horse. From the size and form of the nasal bones, it is deduced, with great probability, that the Palæothere possessed a short movable proboscis or trunk (fig. 352).

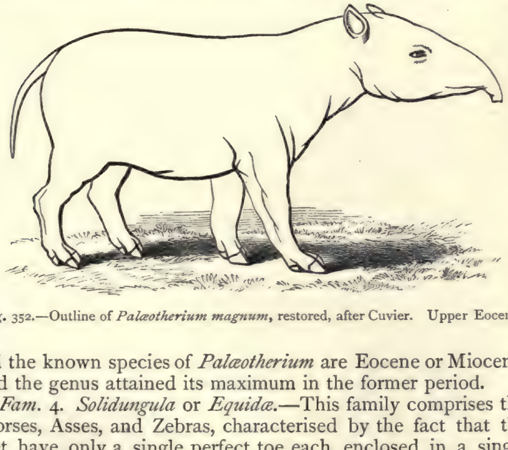


Fig. 352.—Outline of *Palæotherium magnum*, restored, after Cuvier. Upper Eocene.

All the known species of *Palæotherium* are Eocene or Miocene, and the genus attained its maximum in the former period.

Fam. 4. *Solidungula* or *Equidæ.*—This family comprises the Horses, Asses, and Zebras, characterised by the fact that the feet have only a single perfect toe each, enclosed in a single broad hoof. There is a discontinuous series of teeth in each jaw; and in the males, canines are present, but these are wanting in the females. The dental formula is—

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{3-3}{3-3};\ m\,\frac{3-3}{3-3} = 40.$$

The skin is covered with hair, and the neck is furnished with a mane.

Three fossil genera of this family are known—viz., *Anchitherium*, *Hipparion*, and *Equus*, the last of which is represented at the present day by the existing Horses, Asses, and Zebras.

Anchitherium comprises some singular forms from the Upper Eocene and Lower Miocene. In this genus each foot is furnished with a single functional hoofed toe, flanked by two small hoofed digits, which are sufficiently developed to touch the ground. *Anchitherium* is nearly related to *Palæotherium*.

Hipparion is confined to the Upper Miocene and Pliocene deposits, and is distinguished by the fact that each foot possessed a single fully-developed toe, bordered by two functionally useless toes, which did not touch the ground, but simply dangled on each side of the central toe.

In the genus *Equus*, the foot consists of a single developed toe, but there are two rudimentary toes in the form of little bony spines—the so-called "splint-bones"—which are attached to the carpus on either side of the metacarpal of the single functional toe. In the Pliocene period appear, for the first time, remains of horses which, like the present form, possessed only a single toe encased in a single hoof. It is interesting to observe that one of the Pliocene horses (*Equus curvidens*) occurs in South America, though this continent certainly possessed no native horse at the time of its discovery by the Spaniards. About twenty horses—one of them standing no more than two and a half feet in height—have been described from North America, in which continent no indigenous horse existed at the time of its discovery. The *Equus fossilis* of the Post-Pliocene and Recent deposits is specifically undistinguishable from the common horse (*Equus caballus*).

SECTION B. ARTIODACTYLA.—In this section of the Ungulates the number of the toes is even—either two or four—and the third toe in each foot forms a symmetrical pair with the fourth. The dorso-lumbar vertebræ are nineteen in number, and there is no third trochanter on the femur. If true horns are present, these are always in pairs, and are supported by bony horn-cores. The antlers of the Deer are also paired, but they are not to be regarded as true horns. The stomach is always more or less complex, or is divided into separate compartments, and the cæcum is comparatively small and simple.

The section *Artiodactyla* comprises the Hippopotamus, the Pigs, and the whole group of the Ruminants, including Oxen, Sheep, Goats, Antelopes, Camels, Llamas, Giraffes, Deer, &c. Besides these there is an extensive series of fossil forms commencing in the Eocene or Lower Tertiary period, and in many respects filling up the gaps between the living forms.

The group of the Artiodactyle Ungulates may be divided into two sections termed respectively *Omnivora* and *Ruminantia*, according as they live upon a miscellaneous (but chiefly vegetable) diet, or are exclusively vegetable-feeders and chew the cud. In the former are the living families of the *Hippopotamidæ* and *Suida* (Swine), with the extinct group of the *Anoplotheridæ*. In the latter are the *Camelidæ*, *Moschidæ* (Musk-deer), *Cervidæ* (Deer), *Camelopardalidæ* (Giraffes), and *Cavicornia* (Antelopes, Sheep, Goats, and Oxen).

OMNIVORA.

1. *Hippopotamidæ*.—This group contains only the single genus *Hippopotamus*, characterised by the massive heavy body, the short blunt muzzle, the large head, and the presence of teeth of three kinds in both jaws. The incisors are $\frac{2-2}{2-2}$, the canines extremely large, $\frac{1-1}{1-1}$, and the molars, $\frac{7-7}{7-7}$ or $\frac{6-6}{6-6}$, with crowns adapted for grinding vegetable substances. The upper canines are short, but the lower canines are in the form of enormous tusks, with a chisel-shaped edge. The feet are massive, and are terminated by four hoofed toes each. The eyes and ears are small, and the skin is extremely thick, and is furnished with few hairs. The tail is very short.

Several extinct species of *Hippopotamus* are known, but there is only one well-established living form, the *Hippopotamus amphibius* or River-horse, and this is confined to the African continent.

The genus *Hippopotamus* may be divided into two sub-genera, in accordance with the number of the incisor teeth. In the sub-genus *Tetraprotodon*, comprising the living species and most of the fossil forms, there are four incisors in each jaw. In the sub-genus *Hexaprotodon*, comprising several Miocene species from India, there are six incisors in each jaw.

Fig. 353.—Molar tooth of *Hippopotamus*, two-thirds of the natural size. Post-Pliocene.

The best-known fossil species of *Hippopotamus* in Europe is the *H. major*, which is found both in Pliocene and in Post-Tertiary deposits. This species is very nearly allied to the living *H. amphibius;* but it extended its range over the whole of the south of Europe.

In the Tertiary deposits of the Siwalik Hills in India (Miocene) have been discovered several species of Hippopotamus, belonging to the sub-generic type, *Hexaprotodon*.

2. *Suidæ*.—The group of the *Suidæ*, comprising the Pigs, Hogs, and Peccaries, is very closely allied to the preceding; but the feet have only two functional toes, the other two toes being much shorter, and hardly touching the ground. All the three kinds of teeth are present, but they vary a good deal. The canines always are very large, and in the males they usually constitute formidable tusks projecting from the sides of the mouth. The incisors are variable, but the lower ones are always inclined forwards. The molars vary from three to seven on each side of the mouth ($\frac{3-3}{3-3}$ or $\frac{7-7}{7-7}$). The stomach is mostly slightly divided, and is not nearly so complex as in the Ruminants. The snout is truncated and cylindrical, fitted for turning up the ground, and is capable of considerable movement. The skin is more or less abundantly covered with hair, and the tail is very short, or represented only by a tubercle.

The most important genera of the *Suidæ* are *Sus* (Pigs), *Dicotyles* (Peccaries), *Chæropotamus*, *Hyopotamus*, and *Anthracotherium*, of which the three last are extinct.

The genus *Sus*, comprising the true Pigs, appears to have commenced its existence in the Miocene Tertiary. Several species are known from Pliocene deposits; and the Wild Boar (*Sus scrofa*) has been found in Post-Pliocene accumulations (commencing in the præ-glacial forest-bed of Norfolk).

The genus *Dicotyles*, comprising the existing Peccaries, is at present confined to the American continent. The same country also has yielded five fossil species, which have been found in the bone-caves of Brazil, and two of which appear to have been much larger than the living forms.

Chæropotamus comprises some Upper Eocene *Suidæ*, which possess seven molars on each side of each jaw, the first of these (præmolars) being compressed, whilst the others are tuberculate. The canines are short, and are not exserted, as they are in the Wild Boar. *Hyopotamus* is another genus, in which the canines are short. All the species of this latter genus belong to the Upper Eocene and Lower Miocene Tertiary. Lastly, the genus *Anthracotherium* is nearly allied to *Chæropotamus*, with which it agrees in the number and general form of the præmolar and molar teeth. All the known species of this genus belong to the Lower Miocene.

3. *Anoplotheridæ*.—Forming a kind of transition between

the Swine and the true Ruminants, is the extinct group of the *Anoplotheridæ*, from the Lower Tertiary Rocks. The *Anoplotheria* (fig. 354) were slender in form, with long tails, and feet terminated by two hoofed toes each, sometimes with small accessory hoofs. The dentition consisted of six incisors in each jaw, small canines not larger than the incisors, and seven molars on each side, there being no interval or diastema between the molars and the canines.

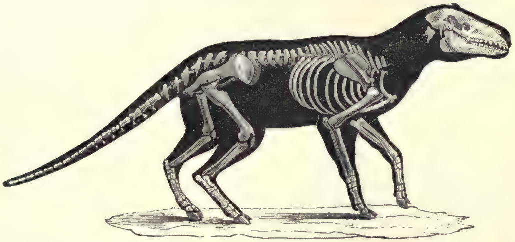


Fig. 354.—*Anoplotherium commune.* Eocene Tertiary.

There was thus a *continuous* series of teeth in each jaw, the dental formula being—

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{4-4}{4-4};\ m\,\frac{3-3}{3-3}=44.$$

The most important genera of this family are *Anoplotherium* and *Xiphodon* of the Upper Eocene, *Chalicotherium* of the Miocene, and *Dichobune* of the Middle Eocene; but many less important genera are known.

RUMINANTIA.

The last section of the *Artiodactyle* Ungulates is the great and natural group of the *Ruminantia*, or Ruminant animals. This section comprises the Oxen, Sheep, Antelopes, Giraffes, Deer, Camels, &c., and is distinguished by the following characters:—

The foot is what is called "cloven," consisting of a symmetrical pair of toes encased in hoofs, and looking as if produced by the splitting into two equal parts of a single hoof. In addition to these functional toes, there are usually two smaller supplementary hoofs placed at the back of the foot. The metacarpal bones of the two functional toes of the fore-limb, and the metatarsal bones of the same toes of the hind-limb, coalesce

to form a single bone, known as the "canon-bone." The stomach is complex, and is divided into several compartments, this being in accordance with their mode of eating. They all, namely, ruminate or "chew the cud"—that is to say, they first swallow their food in an unmasticated or partially-masticated condition, and then bring it up again, after a longer or shorter time, in order to chew it thoroughly.

The dentition of the Ruminants presents peculiarities almost as great and as distinctive as those to be derived from the digestive system. In the typical Ruminants (*e. g.*, Oxen, Sheep, Antelopes), there are no incisor teeth in the upper jaw, their place being taken by a callous pad of hardened gum, against which the lower incisors impinge (fig. 355). There are also no

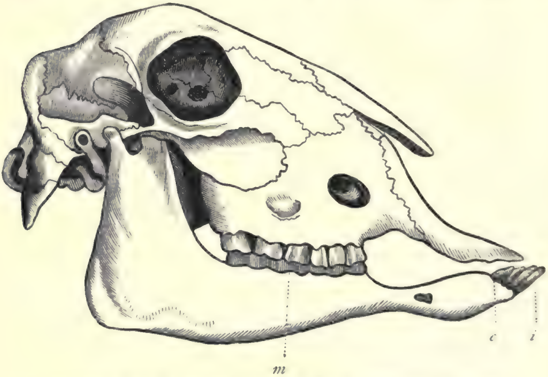


Fig. 355.—Skull of a hornless Sheep (after Owen). *i* Incisors; *c* Canines; *m* Molars and præmolars.

upper canine teeth, and the only teeth in the upper jaw are six molars on each side. In the front of the lower jaw is a continuous and uninterrupted series of eight teeth, of which the central six are incisors, and the two outer ones are regarded by Owen as being canines. Upon this view, canine teeth are present in the lower jaw of the typical Ruminants, and they are only remarkable for being placed in the same series as the incisors, which they altogether resemble in shape, size, and direction. Behind this continuous series of eight teeth in the lower jaw there is a vacant space, which is followed behind by six molars on each side.

The dental formula, then, for a typical Ruminant animal is—

$$i\,\frac{0-0}{3-3};\ c\,\frac{0-0}{1-1};\ pm\,\frac{3-3}{3-3};\ m\,\frac{3-3}{3-3}=32.$$

The departures from this typical formula occur in the *Camelidæ*, the *Moschidæ*, and in some of the Deer. Most of the Deer conform in their dentition to the above formula, but a few forms (*e. g.*, the Muntjak) have canine teeth in the upper jaw. These upper canines, however, are mostly confined to the males; and if they occur in the females, they are of a small size. The dentition of the *Camelidæ* (Camels and Llamas) is still more aberrant; there being two canine-like upper incisors and upper canines as well. The lower canines also are more pointed and stand more erect than the lower incisors, so that they are easily recognisable.

The group of the *Ruminantia* includes the families of the *Camelidæ* (Camels and Llamas), the *Moschidæ* (Musk-deer), the *Cervidæ* (Deer), the *Camelopardalidæ* (Giraffe), and the *Cavicornia* (Oxen, Sheep, Goats, Antelopes).

a. Camelidæ.—The Camels and Llamas constitute in many respects an aberrant group of the *Ruminantia*, especially in their dentition, the peculiarities of which have been spoken of above, and need not be repeated here. In their feet, too, the *Camelidæ* are peculiar. The feet are long and terminate in only two toes, which are covered by imperfect nail-like hoofs, covering no more than the upper surface of each toe. The two hinder supplementary toes, which are mostly present in the Ruminants, are here altogether wanting; and the soles of the feet are covered by a callous horny integument, by which the two toes of each foot are conjoined, and upon which the animal walks. The head in all the *Camelidæ* is destitute of horns, and the nostrils can be closed at the will of the animal.

The two living genera of the *Camelidæ* are *Camelus*, comprising the true Camels, and *Auchenia*, comprising the Llamas and Alpacas of South America. Both of these genera are represented by fossil forms, the former by two species which occur in the Tertiary deposits of the Siwalik Hills, in India, and the latter by two species which occur in the bone-caves of Brazil, and one of which exceeded the horse in size.

Besides these existing genera, there are the two extinct genera *Merycotherium* and *Macrauchenia*. The first of these is only known by some molar teeth, which have been discovered in the drift of Siberia, and which resemble those of the Camel in form. *Macrauchenia* is a remarkable extinct genus, which is in many respects intermediate between the Perissodactyle and

Artiodactyle Ungulates. In fact, as the feet appear to be undoubtedly three-toed, it can only with some violence be considered here as belonging to the Artiodactyles. At the same time, it shows many remarkable points of affinity to the *Camelidæ*, and it may be regarded as a generalised type, presenting resemblances on the one hand to *Palæotherium*, and on the other hand to the Llamas (*Auchenia*). Only a single species is known, which equals the Rhinoceros in size, and occurs in Post-Tertiary or late Tertiary strata in South America.

b. Moschidæ.—The second group is that of the Musk-deer, characterised by the total absence of horns in both sexes, and by the presence of canines in both jaws, those in the upper jaw being in the form of tusks in the males, but being much smaller in the females.

The family *Moschidæ* is a small one, and is of little geological importance. A species of *Moschus*, allied to the living Musk-deer, has been found in India, and another form has been indicated as occurring in the later Tertiary deposits of Europe. The genus *Amphitragulus* has been founded upon remains from the Lower Miocene of France; and the nearly-allied *Dremotherium* has been discovered in the Miocene deposits of France and Attica.

c. Cervidæ.—This family is of much greater importance than that of the *Moschidæ*, including as it does all the true Deer. They are distinguished from the other Ruminants chiefly by the nature of the horns. With the single exception of the Reindeer, these appendages are confined to the males amongst the *Cervidæ*, and do not occur in the females. They do not consist, as in the succeeding group, of a hollow sheath of horn surrounding a central bony core, nor are they permanently retained by the animal. On the other hand, the horns, or, as they are more properly called, the *antlers*, of the *Cervidæ* are deciduous, and are solid. They are bony throughout, and are usually more or less branched, and they are annually shed and annually reproduced at the breeding season. They increase in size and in the number of branches every time they are reproduced, until in the old males they may attain an enormous size.

The living *Cervidæ* are very generally distributed, but no member of the group has hitherto been discovered in either Australia or South Africa, their place in the latter continent seeming to be taken by the nearly-allied Antelopes (distinguished by their hollow horns).

The true *Cervidæ* do not seem to make their appearance before the Miocene period, in which they are represented by

the extinct genus *Dorcatherium*, and by species of the living genus *Cervus*. The former of these appears to have been furnished with upper canines; and the animal had antlers supported upon bony peduncles, in both of these respects resembling the living Muntjak (*Cervus Muntjak*) of India.

The number of known fossil Deer is very considerable, but many forms are only known by fragmentary remains; and it will be sufficient here to speak of some of the more important examples.

Fig. 356.—*Cervus megaceros* (*Megaceros Hibernicus*). The "Irish Elk." Post-Pliocene.

The true Elks, represented by the living Moose (*Alces malchis*, or *A. palmatus*), are distinguished by their antlers without either basal or mesial "tines," but terminated by a great

palmation digitated on its outer side only. Antlers of a species undistinguishable from the existing Moose have been found not uncommonly in Post-Pliocene deposits in various parts of Europe, but this animal does not make its appearance till after the close of the Glacial period.

The Reindeer (*Cervus tarandus*) of Northern Europe and North America is remarkable for being the only member of the *Cervidæ* in which both sexes have horns. The horns are of large size, cylindrical, divided, with basilar and median tynes. Remains of the Reindeer are found, often in considerable abundance, in various Post-Pliocene deposits in Europe, extending as far south as the Pyrenees.

Intermediate between the Reindeer and the Fallow-deer is the celebrated Post-Pliocene species, which is commonly known as the "Irish Elk" (*Cervus megaceros*, or *Megaceros Hibernicus*). This extinct form (fig. 356) is remarkable for its great size and for the enormous dimensions of the spreading antlers, which are expanded towards their extremities, and attain an expanse of as much as ten feet from tip to tip. The *Cervus megaceros* is exclusively Post-Tertiary, but does not appear, so far as is known with certainty, to have survived into the Prehistoric period.

The true Stags (*Cervus*), to which the Irish Elk seems properly to belong, are typified by such species as the Red Deer (*Cervus elaphus*) of Europe, and the Wapiti (*Cervus Canadensis*) of North America. The former of these occurs in a fossil state in Post-Pliocene and Recent deposits in Europe, and the latter is represented in accumulations of the same age in America by a closely-allied or identical form.

The Roebuck (*Cervus capreolus*), distinguished by its branched antlers, with a median, but without a basilar, tyne, is also known in a fossil condition in Post-Pliocene deposits in Europe, appearing before the commencement of the Glacial period.

The Miocene and Pliocene deposits, lastly, have yielded remains of *Cervidæ*, which have been referred to various species; but none of these are sufficiently important to merit especial mention.

d. Camelopardalidæ.—This family includes only a single living animal—the *Camelopardalis Giraffa*, or Giraffe—sometimes called the Camelopard, from the fact that the skin is spotted like that of the Leopard, whilst the neck is long, and gives it some distant resemblance to a Camel. There are no upper canines in the Giraffe, and both sexes possess two small frontal horns, which, however, are persistent, and remain per-

manently covered by a hairy skin, terminated by a tuft of long stiff bristles. The neck is of extraordinary length, but, nevertheless, consists of no more than the normal seven cervical vertebræ. The fore-legs appear to be much longer than the hind-legs, and all are terminated by two toes each, the supplementary toes being altogether wanting.

Fossil species of Giraffe have been discovered in the Tertiary deposits of the Siwalik Hills in India and in the Upper Miocene of Attica; and a species has also been described from France. This last, however, would seem to be referable to the genus *Helladotherium*, founded for the reception of some singular fossils from the Upper Miocene Tertiary of Attica. In this remarkable genus there appear to have been no horns, and the teeth present certain resemblances to those of the Antelopes.

e. Cavicornia.—The last family of the Ruminants is that of the *Cavicornia* or *Bovidæ*, comprising the Oxen, Sheep, Goats, and Antelopes. This family includes the most typical Ruminants, and those of most importance to man. The upper jaw in all the *Cavicornia* is wholly destitute of incisors and canines, the place of which is taken by the hardened gum, against which the lower incisors bite. There are six incisors and two canines in the lower jaw, placed in a continuous series, and the molars are separated by a wide gap from the canines. There are six molars on each side of each jaw. Both sexes have horns, or the males only may be horned, but in either case these appendages are very different from the "antlers" of the *Cervidæ*. The horns, namely, are persistent, instead of being deciduous, and each consists of a bony process of the frontal bone—or "horn-core"—covered by a sheath of horn. The feet are cleft, but are furnished with accessory hoofs placed on the back of the foot.

The *Cavicornia* comprise the three families of the *Antilopidæ*, *Ovidæ*, and *Bovidæ*. The Antelopes form an extremely large section, with very many species. They are characterised by their slender deer-like form, their long and slender legs, and their simple, cylindrical, annulated, or twisted horns, which are usually confined to the males, but sometimes occur in the females as well.

The above definition will not apply in all points to some singular extinct forms usually referred to the *Antilopidæ*, nor to one aberrant existing form—viz., the Prong-buck (*Antilope furcifer*, or *Antilocapra Americana*). This extraordinary and unique species differs from the typical Antelopes in having no accessory hoofs, in having horns which have a snag in front,

and in the fact that the outer sheath of the horn is *deciduous*, and not permanent. For these reasons, it has been proposed to place the Prong-buck in a separate family (the *Antilocapridæ*); but it is more convenient here to consider it as an aberrant member of the *Antilopidæ*.

Several species of Antelope have been described from the Miocene and Pliocene deposits of Europe, but none of them are of any special importance. Fossil Antelopes have also been discovered in the bone-caves of Brazil, though no member of this family is known at the present day as existing in South America. By far the most remarkable fossils, however, which have been generally referred to the *Antilopidæ*, are those on which the genera *Sivatherium* and *Bramatherium* have been founded.

Sivatherium (fig. 357) is known by the single species *S. giganteum*, discovered by Dr Falconer and Sir Proby Cautley in the Tertiary deposits of the Siwalik Hills in India. The

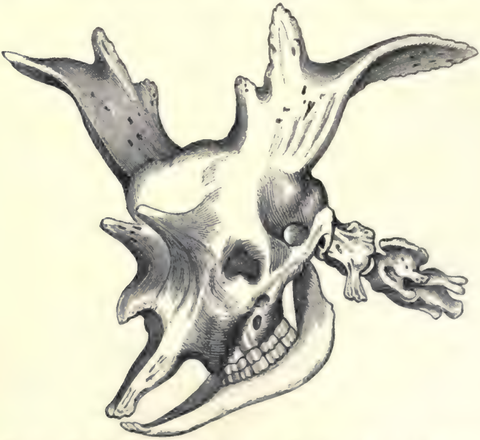


Fig. 357.—Skull of *Sivatherium giganteum*. Pliocene, India. (After Murie.)

most important peculiarity in *Sivatherium* is the structure of the horns, of which the animal possessed two pairs. Both pairs of horns were supported by bony "cores," so that there can be no hesitation in referring *Sivatherium* to the group of

the *Cavicornia.* The anterior horns, as shown by the shape of the horn-cores, were simple; and if the posterior horns had been of a similar form, then *Sivatherium* might have been fairly regarded as merely a gigantic four-horned Antelope, similar to the living *Antilope* (*Tetraceros*) *quadricornis* of India. The posterior horns, however, are not only much larger than the anterior, but they possess two snags or branches—a peculiarity not to be paralleled amongst existing *Cavicornia*, except in the Prong-buck. Dr Murie, however, in an admirable paper on the affinities of *Sivatherium*, has drawn attention to the fact that the Prong-buck sheds the sheath of its horns annually, and has suggested that this may have also been the case with the extinct form. This hypothesis is rendered probable, amongst other reasons, by the fact that no sheath has as yet been discovered surrounding the horn-cores of either pair of horns in the *Sivatherium.* Upon the whole, therefore, the above-mentioned zoologist would refer *Sivatherium* to a distinct group which he terms *Sivatheridæ*, and regards as being most nearly related to the *Antilocapridæ.*

Bramatherium has been found in deposits of the same age as *Sivatherium*, with which it agrees in its colossal dimensions and its possession of two pairs of hollow horns. It differs from *Sivatherium*, however, in certain details of minor importance.

The Sheep and Goats (*Ovidæ*) have mostly horns in both sexes, and the horns are generally curved, compressed, and turned more or less backwards. The body is heavier, and the legs shorter and stouter, than in the true Antelopes. In the true Goats (*Capra*) both sexes have horns, and there are no lachrymal sinuses. The true Sheep (*Ovis*) are destitute of a beard, and the horns are generally twisted into a spiral. Horns may be present in both sexes, or in the males only.

The Sheep and Goats are of no importance as fossils, unless, indeed, as believed by high authorities, the Musk-ox should be referred to the *Ovidæ.* Here, however, it will be considered as belonging to the *Bovidæ.* Remains of both Sheep and Goats have been discovered in various Post-Tertiary deposits in Europe, but they present nothing of special interest.

The true Oxen (*Bovidæ*) are distinguished by having simple horns, of a rounded shape, not twisted into a spiral. A few remains of *Bovidæ* have been found in deposits of Pliocene age, but the Oxen are essentially Post-Pliocene and Recent. The most important Fossil Oxen are the *Urus*, the Aurochs, the *Bos longifrons* of Owen, and the Musk-ox.

The Aurochs or Lithuanian Bison (*Bos bison*) can hardly be considered as a fossil form, as it occurs in a living state in

Europe at the present day. Remains, however, of this large ox are found in various prehistoric deposits.

The *Bos longifrons* of Owen, or "Small Short-horn," is in a similar position to the Aurochs. According to Mr Boyd Dawkins, this form (which is identical with the *Bos frontosus* of Nilsson) has not been proved to occur in any Post-Pliocene deposit, though it occurs plentifully in the bone-caves and alluvia of the Recent or prehistoric period. It is believed by the same high authority that the *Bos longifrons* is the ancestor of our present Welsh or Scotch Cattle.

The *Urus* or Wild Bull (*Bos primigenius*), though much larger than our ordinary oxen, is believed to be specifically undistinguishable from the domestic Ox (*Bos taurus*), and it was probably the parent of the larger varieties of European

Fig. 358.—Skull of the Urus (*Bos primigenius*). Post-Pliocene and Recent.

Oxen. It was a contemporary of the Mammoth, Woolly Rhinoceros, Cave Lion, Cave Bear, Irish Elk, and other Post-Pliocene Mammals, and it was in existence up to at least the twelfth century.

The last of the Oxen which deserves notice is the curious Musk-ox (*Ovibos moschatus*). This singular animal is at the present day a native of Arctic America, and is remarkable for the great length of the hair. It is called the Musk-ox, because it gives out a musky odour. Like the Reindeer, the Musk-ox had formerly a much wider geographical range than it has at present—the conditions of climate which are necessary for its existence having at that time extended over a very much

larger area than at present. The Musk-ox, in fact, in Post Tertiary times is known to have extended over the greater part of Europe, remains of it occurring abundantly in certain of the bone-caves of France. As already mentioned, high authorities regard the Musk-ox as being truly a large Sheep, and as being, therefore, referable to the *Ovidæ*.

CHAPTER XXXIX.

ORDERS OF MAMMALIA—Continued.

Hyracoidea and Proboscidea.

Order VII. Hyracoidea.—This is a very small order which has been constituted by Huxley for the reception of two or three little animals, which make up the single genus *Hyrax*. These have been usually placed in the immediate neighbourhood of the Rhinoceros, to which they have some decided affinities, and they are still retained by Owen in the section of the Perissodactyle Ungulates.

The order is distinguished by the following characters:— There are no canine teeth, and the incisors of the upper jaw are long and curved, and grow from permanent pulps, as they do in the Rodents (such as the Beaver, Rat, &c.) The molar teeth are singularly like those of the Rhinoceros. According to Huxley, the dental formula of the aged animal is—

$$i\,\frac{2-2}{2-2};\; c\,\frac{0-0}{0-0};\; pm\,\frac{4-4}{4-4};\; m\,\frac{3-3}{3-3} = 36.$$

The fore-feet are tetradactylous, the hind-feet tridactylous, and all the toes have rounded hoof-like nails, with the exception of the inner toes of the hind-feet, which have an obliquely-curved nail. There are no clavicles. The nose and ears are short, and the tail is represented by a mere tubercle.

The living species of *Hyrax* inhabit Syria, Palestine, and South Africa. No fossil representative of the order has as yet been discovered. The *Hyracotherium* of the Eocene Tertiary, however, received its name from its supposed affinities to the living *Hyrax*.

Order VIII. Proboscidea.—The eighth order of Mammals is that of the *Proboscidea*, comprising no other living animals

except the Elephants, but including also the extinct *Mastodon* and *Deinotherium*.

The order is characterised by the total absence of canine teeth; the molar teeth are few in number, large, and transversely ridged or tuberculate; incisors are always present, and grow from persistent pulps, constituting long tusks (fig. 359).

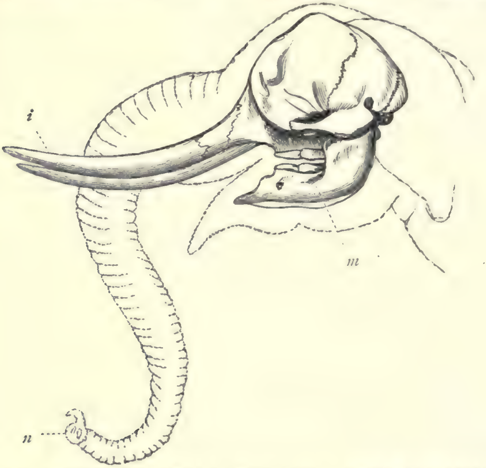


Fig. 359.—Skull of the Indian Elephant (*Elephas Indicus*). *i* Tusk-like upper incisors; *m* Lower jaw, with grinding molars, but without incisors; *n* Nostrils, placed at the extremity of the proboscis.

In all the Elephants there are two of these tusk-like incisors in the upper jaw, and the lower jaw is without incisor teeth. In the *Deinotherium* this is reversed, there being two tusk-like lower incisors and no upper incisors. In the Mastodons, the incisors are usually developed in the upper jaw, and form tusks, as in the Elephants; but sometimes there are both upper and lower incisors, and both are tusk-like. The nose is prolonged into a cylindrical trunk, movable in every direction, highly sensitive, and terminating in a finger-like prehensile lobe (fig. 359). The nostrils are placed at the extremity of the proboscis. The feet are furnished with five toes each, but these are only partially indicated externally by the divisions of the hoof. The feet are furnished with a thick pad of integument, forming the

palms of the hand and the soles of the feet. There are no clavicles. The testes are abdominal throughout life. There are two teats, and these are placed upon the chest.

The order *Proboscidea* comprises the three genera, *Elephas* (with both living and extinct representatives), *Mastodon*, and *Deinotherium*, the two latter being extinct. The order came into existence in the Miocene period, in which it is represented by all these three genera. The genus *Elephas* comprises the living Asiatic and Indian Elephants. In all the Elephants, whether living or extinct, the "tusks" are formed by an enormous development of the upper incisors. The milk-tusks are early shed, and never attain any great size. The permanent tusks, however, grow from persistent pulps, attaining in old males an enormous size. The lower incisors are absent, and there are no other teeth in the jaws except the large molars, which are usually two in number on each side of each jaw. The molar teeth are of very large size, and are composed of a number of transverse plates of enamel united together by dentine. In the Indian Elephant the transverse ridges of enamel are narrow and undulating, whilst in the African Elephant they enclose lozenge-shaped intervals.

The surfaces of the molars are approximately flat, and the plates of enamel form patterns which are very characteristic of

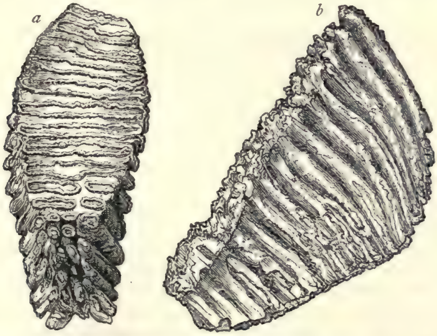


Fig. 360.—Molar of the Mammoth (*Elephas primigenius*), upper jaw, right side, half natural size. Post-Pliocene. *a* Grinding surface ; *b* Side view.

the different species. Subjoined are illustrations of the molars of three of the most important Post-Pliocene Elephants (figs. 360–362).

No Elephant has as yet been discovered in the Miocene deposits of Europe, but six species are known from strata of this age in India. In the Pliocene period, Europe possessed its Elephants, of which the most important is the *Elephas antiquus* (fig. 362). This is essentially a southern form, and is found in Pliocene strata in France and Italy. It survived the Glacial period, and is found abundantly in various Post-Pliocene deposits. It abounded in Post-Pliocene times chiefly in Southern Europe, south of the Alps and Pyrenees; and it is only on the northern edge of this area that its remains are found commingled with those of the Mammoth.

Fig. 361.—Molar tooth of *Elephas meridionalis*, one-third of natural size. Pliocene and Post-Pliocene. (After Lyell.)

Fig. 362.—Molar tooth of *Elephas antiquus*. Penultimate molar, one-third of natural size. Post-Pliocene and Pliocene. (After Lyell.)

Of the Post-Pliocene Elephants by far the best-known and most important is the Mammoth (*Elephas primigenius*). This remarkable form (fig. 363) was essentially northern in its distribution, never passing south of a line drawn through the Pyrenees, the Alps, the northern shores of the Caspian, Lake Baikal, Kamschatka, and the Stanovi Mountains (Dawkins). It occurs in the præ-Glacial forest-bed of Cromer in Norfolk, survived the Glacial period, and is found abundantly in Post-Glacial deposits in France, Germany, Britain, Russia in Europe, Asia, and North America, being often associated with the Rein-

deer, Lemming, and Musk-ox. That it survived into the earlier portion of the human period is unquestionable, its remains having been found in a great number of instances associated

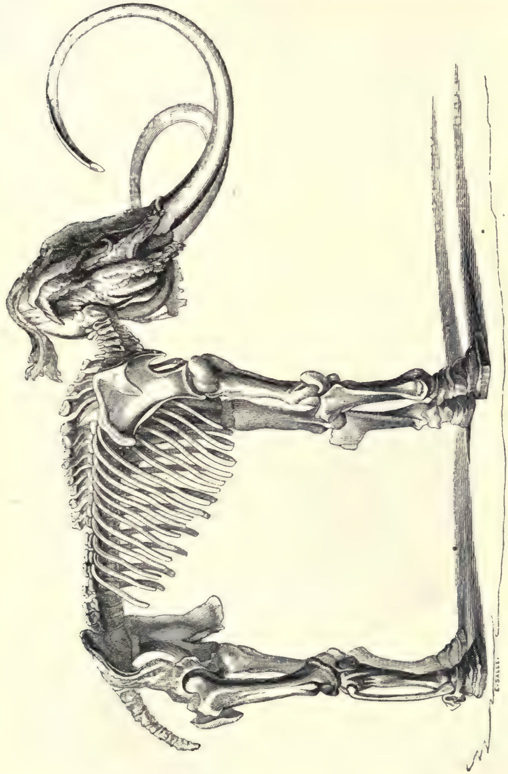


Fig. 363.—Skeleton of the Mammoth (*Elephas primigenius*). Post-Pliocene.

with implements of human manufacture; whilst in one instance a recognisable portrait of it has been discovered, carved on bone. From its great abundance in Siberia, it might have been safely inferred that the Mammoth was able to endure a much

colder climate than either of the living species. This inference, however, has been rendered a certainty by the discovery of the body of more than one Mammoth embedded in the frozen soil of Siberia. These specimens had been so perfectly preserved that even microscopical sections of some of the tissues could be made; and in one case even the eyes were preserved. From these specimens, we know that the body of the Mammoth was covered with long woolly hair.

Amongst other Elephants which occur in Post-Pliocene deposits, may be mentioned, as of special interest, the pigmy Elephants of Malta. One of these—the *Elephas Melitensis*, or so-called "Donkey-Elephant"—was not more than four and a half feet in height. The other—the *Elephas Falconeri*, of Busk—was still smaller, its average height at the withers not exceeding two and a half to three feet.

The *Mastodons* in most respects closely resemble the true Elephants, from which they are distinguished by their dentition. As in the Elephants, the upper incisors grow from permanent pulps, and constitute long tusks; but in the majority of cases the Mastodons also possess lower incisors as well.

Fig. 364.—Third milk-molar of the left side of the upper jaw of *Mastodon Arvernensis*, showing the grinding surface. Pliocene. (After Lyell.)

The two lower incisors, however, though tusk-shaped, did not develop themselves to any extent, and often disappeared in adult life. A more important distinction between the Elephants and Mastodons is that the molar teeth of the latter are not only more numerous, but have the peculiarity that their crowns are furnished with nipple-shaped eminences or tubercles placed in pairs (fig. 364). The Mastodons appear to have commenced their existence in the Miocene period, being re-

presented in strata of this age by four European and three Indian species. In the Pliocene period, also, remains of *Mastodon* are not infrequent; and in North America the great *M. Ohioticus* occurs plentifully in deposits of Post-Pliocene age.

The last of the *Proboscidea* is the remarkable Miocene Mammal known as the *Deinotherium*, which is still referred by some high authorities to the order *Sirenia*.

Fig. 365.—Skull of *Deinotherium giganteum*. Miocene Tertiary.

This extraordinary animal has hitherto only been found in Miocene deposits, and little is known of it except its enormous skull (fig. 365). Molars and præmolars were present in each jaw, and the upper jaw was destitute of canines and incisors. In the lower jaw were two very large tusk-like incisors, which were not directed forwards as in the true Elephants, but were bent abruptly downwards (fig. 365). The animal must have attained an enormous size, and it is probable that the curved tusks were used either in digging up roots or in mooring the animal to the banks of rivers, for it was probably aquatic or semi-aquatic in its habits.

Several species of *Deinotherium* have been indicated as occurring in Europe, and a species has been noticed in the Tertiary deposits of the Siwalik Hills by Dr Falconer and Sir Proby Cautley.

CHAPTER XL.

ORDERS OF MAMMALIA—Continued.

CARNIVORA.

ORDER IX. CARNIVORA.—The ninth order of Mammals is that of the *Carnivora*, comprising the *Feræ*, or Beasts of Prey, along with the old order of the *Pinnipedia*, or Seals and Walruses, these latter being now universally regarded as merely a group of the *Carnivora* modified to lead an aquatic life.

The *Carnivora* are distinguished by always possessing two sets of teeth, which are simply covered by enamel, and are always of three kinds—incisors, canines, and molars—differing from one another in shape and size. The incisors are generally $\frac{3-3}{3-3}$ (except in some Seals); the canines are always $\frac{1-1}{1-1}$, and are invariably much larger and longer than the incisors. The præmolars and molars are mostly furnished with cutting or trenchant edges; but they graduate from a cutting to a tuberculate form, as the diet is strictly carnivorous, or becomes more or less miscellaneous. In the typical Carnivores (such as the Lion and Tiger), the last tooth but one in the upper jaw, and the last tooth in the lower jaw, are known as the "carnassial" teeth, having a sharp cutting edge adapted for dividing flesh, and generally a more or less developed tuberculated heel or process. A varying number, however, of the molars and præmolars may be "tuberculate," their crowns being adapted for bruising rather than cutting. As a general rule, the shorter the jaw, and the fewer the præmolars and molars, the more carnivorous is the animal. The jaws are so articulated as to admit of vertical but not of horizontal movements; the zygomatic arches are greatly developed to give room for the powerful muscles of the jaws; and the orbits are not separated from the temporal fossæ.

In all the *Carnivora* the clavicles are either altogether wanting, or are quite rudimentary. The toes are provided with sharp curved claws.

The order *Carnivora* is divided into three very natural sections:—

Section I. Pinnigrada or *Pinnipedia.*—This section comprises the Seals and Walruses, in which the fore and hind limbs are short, and are expanded into broad, webbed swimming-paddles (fig. 366, B.) The hind-feet are placed very far back, nearly in a line with the axis of the body, and they are more or less tied down to the tail by the integuments.

Section II. Plantigrada.—This section comprises the Bears and their allies, in which the whole, or nearly the whole, of the foot is applied to the ground, so that the animal walks upon the *soles* of the feet (fig. 366, A.)

Section III. Digitigrada.—This section comprises the Lions, Tigers, Cats, Dogs, &c., in which the heel of the foot is raised entirely off the ground, and the animal walks upon the tips of the toes (fig. 366, C.)

As regards their general distribution in time, if the little *Mi-*

crolestes of the Upper Trias be *Marsupial*, as is almost certainly the case, then the order *Carnivora* is comparatively modern, the earliest undoubted remains having been found in the Eocene Tertiary. In the Eocene period, however, the families of the *Canidæ* and *Felidæ* appear to have been already differentiated. The *Ursidæ*, *Viverridæ*, *Mustelidæ*, *Hyænidæ*, and *Phocidæ*, do not seem to have made their appearance before the Miocene period. In the Pliocene and Post-Pliocene periods almost all the existing types of the *Carnivora* are represented by extinct forms, whilst in the latter the remains of various living species are found associated with other animals which have at the present day entirely passed away. In the following are given the characters and chief fossil forms of the families of the *Carnivora*.

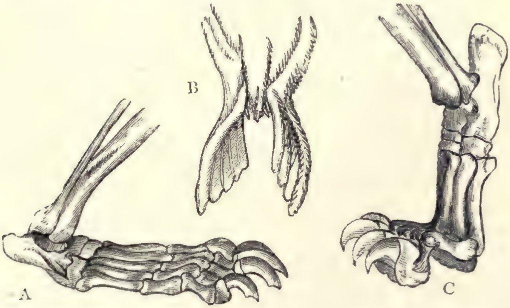


Fig. 366.—Feet of *Carnivora* (after Owen). A, *Plantigrada*, Foot of Bear; B, *Pinnigrada*, Hind-feet of Seal; C, *Digitigrada*, Foot of Lion.

SECTION I. PINNIGRADA.—This section of the *Carnivora* comprises the amphibious Seals and Walruses, which differ from the typical Carnivores merely in points connected with their semi-aquatic mode of life. The body is elongated, somewhat fish-like in shape, and terminated by a short conical tail. All the four limbs are present, but they are very short, and the five toes of each foot are united by the integuments, so as to form powerful swimming-paddles. The hind-feet are placed very far back, their axis nearly coinciding with that of the body (fig. 366, B). Owing to this circumstance the hinder end of the body forms an admirable swimming apparatus, similar in its action to the horizontal tail-fin of the *Cetacea* and *Sirenia*. The tips of the toes are furnished with strong claws, but the powers of terrestrial locomotion are very limited. The ears are

of small size, and are mostly only indicated by small apertures, which the animal has the power of closing when under water. The bones are light and spongy, and beneath the skin is a layer of fat or blubber. The dentition varies; but teeth of three kinds are always present, in the young animal at any rate. The canines are always long and pointed, and the molars are generally furnished with sharp cutting edges.

The Seals (*Phocidæ*) are distinguished by having incisor teeth in both jaws, and by the fact that the canines are not immoderately developed. As regards their distribution in time, the Seals are indicated as occurring in the Miocene and Pliocene Tertiary; but their remains are by no means as abundant as might have been anticipated from their aquatic habits. Remains of Seals, however, are by no means very rare in Post-Tertiary deposits.

The Walruses (*Trichecidæ*) are distinguished from the Seals by their enormously-developed upper canines, which grow from persistent pulps, and constitute great pointed tusks. Remains of the Walrus have been found in some of the later Tertiary deposits, but they are merely fragmentary, and are of little importance.

SECTION II. PLANTIGRADA.—The Carnivorous animals belonging to this section apply the whole or the greater part of the sole of the foot to the ground (fig. 366, A); and the portion of the sole so employed is destitute of hairs in most instances (the sole is hairy in the Polar Bear).

The typical family of the Plantigrade *Carnivora* is that of the *Ursidæ* or Bears, in which the entire sole of the foot is applied to the ground in walking. The *Ursidæ* are much less purely carnivorous than the majority of the order, and, in accordance with their omnivorous habits, the teeth do not exhibit the typical carnivorous characters. The incisors and canines have the ordinary carnivorous form, but the "carnassial" or sectorial molar has a tuberculate crown instead of a sharp cutting edge. The dental formula is—

$$i\,\frac{3-3}{3-3};\; c\,\frac{1-1}{1-1};\; pm\,\frac{4-4}{4-4};\; m\,\frac{2-2}{3-3} = 42.$$

The claws are large, strong, and curved, but are not retractile. The tongue is smooth; the ears small, erect, and rounded; the tail short; the nose forms a movable truncated snout; and the pupil is circular.

The oldest known member of the *Ursidæ* is the *Amphicyon* of the Miocene Tertiary. In this genus the molars are tuberculated, as they are in the true Bears; but, unlike the latter,

there is an additional molar on each side of the upper jaw. Several species have been described from deposits of Middle Tertiary age.

The true Bears (*Ursus*) do not appear, so far as is certainly known, to have commenced their existence before the Pliocene period, the best-known species of this epoch being the *Ursus Arvernensis*. In the Post-Tertiary period the two most important species are the *Ursus priscus* and *Ursus spelæus*, of which the former is probably identical with the living Grizzly Bear (*Ursus ferox*). The Cave-bear (*Ursus spelæus*, fig. 367)

Fig. 367.—Skull of *Ursus spelæus*. Post-Pliocene.

is a gigantic Bear, which, as its name implies, has been found mainly in cavern-deposits. The size of this species considerably exceeded that of any existing Bear, and it is especially characteristic of the later portion of the Post-Pliocene period.

More or less nearly allied to the true Bears are the little living animals which are known as Coatis (*Nasua*), Racoons (*Procyon*), and Kinkajous (*Cercoleptes*), all of which at the present day are confined to the American continent. The bone-caves of Brazil have yielded remains of two species of *Nasua*, and a Racoon has been found in Post-Tertiary deposits in Illinois. No certain remains of *Cercoleptes* are known; but the *Arctocyon primævus* of the Eocene Tertiary of France has been compared with the existing Kinkajous.

The only remaining family of the *Plantigrada* is that of the *Melidæ* or Badgers, characterised by their elongated bodies and short legs, and by the fact that the carnassial tooth has a partly cutting edge, and is not wholly tuberculate as in the Bears.

Remains of Badgers have been found in Post-Tertiary deposits in Europe, and they are probably referable to the existing *Meles taxus*. The Gluttons (*Gulo*) are also only known from Post-Tertiary accumulations, and the so-called *Gulo spelæus* of the cavern-deposits of Europe does not appear to be separable from the common Wolverine (*Gulo luscus*).

SECTION III. DIGITIGRADA.—In this section of the *Carnivora* the heel is raised above the ground, with the whole or the greater part of the metacarpus, so that the animals walk more or less completely on the tips of the toes (fig. 366, C). No absolute line, however, of demarcation can be drawn between the Plantigrade and Digitigrade sections of the *Carnivora*, since many forms (*e.g.*, *Mustelidæ* and *Viverridæ*) exhibit transitional characters, and it has even been proposed to place these in a separate section, under the name of *Semi-plantigrada*.

The first family of the *Digitigrada* is that of the *Mustelidæ* or Weasels, including a number of small Carnivores, with short legs, elongated worm-like bodies, and a peculiar gliding mode of progression (hence the name of *Vermiformes*, sometimes applied to the group).

The most important fossil forms of the *Mustelidæ* belong to the genera *Mustela* (comprising the Weasels and Stoats), and *Lutra* (comprising the Otters). The Weasels appear to have come into existence in the Miocene period, being represented by several species in deposits belonging to this age. They occur also in Pliocene and Post-Tertiary deposits. The Otters are likewise known by their remains in strata of Miocene and Pliocene age, and they occur in Post-Tertiary times.

The second family of the Semi-plantigrade Carnivores is that of the *Viverridæ*, the Civets and Genettes. They are all of moderate size, with sharp muzzles and long tails, and more or less striped, or banded, or spotted. The carnassial molar is trenchant; the canines are long, sharp, and pointed; and the tongue is roughened by numerous prickly papillæ. The claws are semi-retractile, and the pupils can contract, on exposure to light, till they resemble a mere line.

The genus *Palæonyctis* of De Blainville has been founded upon a lower jaw obtained from the Eocene Tertiary of France, and apparently referable to this family. The Miocene rocks of France have yielded the remains of several species which have been placed in the existing genus *Viverra*. Lastly, the *Hyænictis* and *Ictitherium* of the Upper Miocene deposits of Attica, appear to be intermediate in their characters between the *Viverridæ* and *Hyænidæ*.

Forming a transition between the *Viverridæ* and the *Felidæ* is the family of the *Hyænidæ*, distinguished by the fact that, alone of all the *Carnivora*, both pairs of feet have only four toes each. The hind-legs are shorter than the fore-legs, so that the trunk sinks towards the hind-quarters, and the tail is short. The tongue is rough and prickly. The head is extremely broad, the muzzle rounded, and the muscles of the jaw extremely powerful and well developed. The claws are non-retractile. All the molars are trenchant except the last upper molar, which is tuberculate. The upper carnassial has a small internal tubercle, and the lower carnassial is wholly trenchant.

The earliest fossil member of the *Hyænidæ* is the *Hyæna Hipparionum* of the Pliocene of France, and other species have been obtained in the same country from strata of the same age. Of the Post-Tertiary Hyænas, the best known and most important is the great Cave-hyæna (*Hyæna spelæa*, fig. 368). This species in many respects resembles the *Hyæna crocuta* of

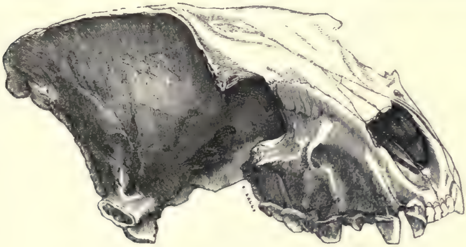


Fig. 368.—Skull of *Hyæna spelæa*. Post-Pliocene.

South Africa; and it inhabited Britain and the greater part of Europe during the Post-Pliocene period. Its remains often occur in great abundance, and no doubt can be entertained as to its having survived into the human period.

Here may be considered the genus *Hyænodon*, which cannot be referred either to the *Hyænidæ* or *Felidæ*. This remarkable genus has been detected in the Eocene Tertiary of England, and the Miocene in France, and is noticeable for the great number of its molars, as compared with the existing *Felidæ*. The dental formula is—

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{4-4}{4-4};\ m\,\frac{3-3}{3-3}=44.$$

All the præmolars and molars possessed trenchant edges,

and were compressed, so that the dentition of this extinct genus is more highly carnivorous than is the case with any existing Carnivore.

The next family is that of the *Canidæ*, comprising the Dogs, Wolves, Foxes, and Jackals. The members of this family are characterised by having pointed muzzles, smooth tongues, and non-retractile claws. The fore-feet have five toes each, the hind-feet have only four. The molar teeth are $\frac{6-6}{7-7}$, sometimes $\frac{7-7}{7-7}$, and of these, two or three on each side are tuberculate. The carnassial has a tolerably large heel or process.

Fig. 369.—Skull of Jackal (*Canis aureus*).

The true Dogs and the Wolves, forming the genus *Canis*, and the Foxes (*Vulpes*), can hardly be distinguished from one another, as fossils, with any certainty. The oldest known member of the *Canidæ* is the *Canis Parisiensis* of the Upper Eocene Tertiary (Gypseous series of Montmartre), which appears to be nearly allied to the existing Arctic Fox (*Vulpes lagopus*). Other species of *Canis* occur in the Miocene, Pliocene, and Post-Tertiary deposits; and the so-called *Canis familiaris fossilis* of the caves of Germany, Belgium, and France, appears to be very nearly allied to the domestic Dog of the present day. Similarly, the so-called *Canis spelæus*, and *Canis vulpes spelæus* are nearly, if not quite, identical with the existing Wolf and Fox of Europe. Lastly, the *Galæcynus* of the Pliocene schists of Oeningen, and the *Palæocyon* (Lund) of the Brazilian caves, are two extinct genera which may be provisionally referred to the *Canidæ*.

The last group of the *Digitigrada* is that of the *Felidæ*, or Cat tribe, comprising the most typical members of the whole order of the *Carnivora*, such as the Lions, Tigers, Leopards, Cat, and Panthers. The members of this family all walk upon the tips

of their toes, the soles of their feet being hairy, and the whole of the metacarpus and heel being raised above the ground (fig. 366, C). The jaws are short, and, owing to this fact, and to the great size of the muscles concerned in mastication, the head assumes a short and rounded form, with an abbreviated and rounded muzzle. The molars and præmolars are fewer in number than in any other of the *Carnivora* (hence the shortness of the jaws), and they are all trenchant, except the last molar in the upper jaw, which is tuberculate. The upper carnassial has three lobes, and a blunt heel or internal process. The lower carnassial has two cutting lobes, and no internal process. According to Owen, the dental formula is—

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{3-3}{2-2};\ m\,\frac{1-1}{1-1}=30.$$

The legs are nearly of equal size, and the hind-feet have only four toes each, whilst the fore-feet have five. All the toes are furnished with strong, curved, retractile claws, which, when not in use, are withdrawn within sheaths by the action of elastic ligaments, so as not to be unnecessarily blunted.

Fig. 370.—Skull of Lion (*Felis leo*).

The *Felidæ* probably came into existence in the Eocene period; but there is considerable uncertainty as to the remains which have been cited from deposits of this age. Several species of *Felis* have been indicated as occurring in Miocene deposits, and still more numerous forms have been determined from Pliocene strata. The most important and best known of the Post-Pliocene *Felidæ* is the great Cave-lion (*Felis spelæa*), which does not appear to be separable by any character of importance from the existing Lion (*Felis leo*). This species inhabited Britain in times subsequent to the Glacial period, and

was a contemporary of the Cave-hyæna, Cave-bear, Woolly Rhinoceros, and Mammoth. There can also be no doubt but that the Cave-lion survived into the earlier portion of the human period.

The only other member of the *Felidæ* which deserves mention, is the "sabre-toothed" Tiger (*Machairodus*), species of which are known to have existed from the Miocene period up to the Post-Pliocene. In this singular genus the upper canines were greatly elongated, trenchant, and sabre-shaped, with finely-serrated margins. There is no upper true molar, and the præmolars are reduced to two on each side of each jaw. The dental formula is—

$$i\,\frac{3-3}{3-3}\,;\ c\,\frac{1-1}{1-1}\,;\ pm\,\frac{2-2}{2-2}\,;\ m\,\frac{0-0}{1-1} = 26.$$

Species of *Machairodus* must have been as large as a Lion; and the genus is not only European, but is also represented by a form in South America, and another in India.

CHAPTER XLI.

ORDERS OF MAMMALIA—Continued.

RODENTIA, CHEIROPTERA, AND INSECTIVORA.

ORDER X. RODENTIA.—The tenth order of Mammals is that of the Rodents, often spoken of as *Glires*, comprising the Mice, Rats, Squirrels, Rabbits, Hares, Beavers, &c.

The *Rodentia* are characterised by the possession of two long curved incisor teeth in each jaw, separated by a wide interval from the molars. The lower jaw never has more than two of these incisors, and the upper jaw very rarely; but sometimes there are four upper incisors. There are no canine teeth, and the molars and præmolars are few in number (rarely more than four on each side of the jaw). The feet are usually furnished with five toes each, all of which are armed with claws; and the hallux, when present, does not differ in form from the other digits.

The most characteristic point about the Rodents is to be found in the structure of the incisors, which are adapted for continuous gnawing—hence the name of *Rodentia*. The incisor teeth are commonly two in each jaw, and they grow from

persistent pulps, so that they continue to grow throughout the life of the animal. They are large, long and curved (fig. 371,

Fig. 371.—A, Skull of the Beaver (after Owen). B, Diagram of the incisor teeth of a Rodent, showing the chisel-shaped point: *a* Enamel; *d* Dentine.

B), and are covered anteriorly by a plate of hard enamel. The back part of each incisor is composed only of the comparatively soft dentine, so that when the tooth is exposed to attrition, the soft dentine behind wears away more rapidly than the hard enamel in front. The result of this is that the crown of the tooth acquires by use a chisel-like shape, bevelled away behind, and the enamel forms a persistent cutting edge (fig. 371).

The gnawing action of the incisors is assisted by the articulation of the lower jaw, the condyle of which is placed longitudinally and not transversely, so that the jaw slides backwards and forwards. The molars, consequently, have flat crowns, the enamelled surfaces of which are always arranged in transverse ridges, in opposition to the antero-posterior movement of the jaw.

The earliest known traces of the Rodents in past time have been discovered in the Eocene Tertiary. The order comprises a large number of families, only the more important of which can be noticed here.

Fam. 1. *Leporidæ*.—In this family are the Hares and Rabbits (*Lepus*), and the Pikas (*Lagomys*), distinguished amongst the Rodents by the possession of two small incisors in the upper jaw, placed behind the central chisel-shaped incisors, so that there are four upper incisors in all. The molars and præmolars are rootless, and the dental formula is—

$$i\,\frac{2-2}{1-1};\ c\,\frac{0-0}{0-0};\ pm\,\frac{3-3}{2-2};\ m\,\frac{3-3}{3-3} = 28.$$

The clavicles are imperfect. The fore-legs are furnished

with five toes, and are considerably shorter than the hind-legs, which have only four toes. The two orbits communicate by an aperture in the septum. Generally there is a short erect tail.

Species of *Lepus*, more or less nearly allied to the existing Hares and Rabbits, are found in the Miocene and Pliocene Tertiary of Europe; whilst the Post-Tertiary deposits of the same area have yielded remains almost or quite identical with living species. The cave-deposits of Brazil have also yielded the bones of a hare very nearly allied to the living *Lepus Brasiliensis*. The Calling Hares or Pikas (*Lagomys*), which are distinguished by their nearly complete clavicles and rudimentary tail, and which at the present day are characteristic of Siberia, are found in the Pliocene of Oeningen and in Post-Tertiary deposits in Britain and Southern Europe.

Fam. 2. *Cavidæ*.—In this family are the living Capybaras (*Hydrochærus*), Agoutis (*Dasyprocta*), Pacas (*Cœlogenys*), &c., characterised by their absence of clavicles, their rudimentary tail, their unguiculate toes, and their general possession of eight rootless molars in each jaw. Almost all the existing members of this family belong to South America, and this continent has been peopled during Post-Tertiary times with numerous species more or less nearly allied to living forms. Thus, the Brazilian bone-caves have yielded to the researches of Lund remains of Guinea-pigs (*Anœma*), Agoutis, Pacas, and Capybaras, all of which appear to belong to extinct species.

Fam. 3. *Hystricidæ*.—In this family are the well-known Porcupines, distinguished from the other Rodents by the fact that the body is covered with long spines or "quills," mixed with bristly hairs. They have four molars on each side of each jaw, and they possess imperfect clavicles.

Remains of Porcupines allied to the existing species of *Hystrix* have been detected in the Pliocene and Post-Pliocene deposits of Europe and Asia. On the other hand, the bone-caves of Brazil have yielded the remains of a Porcupine with a prehensile tail, allied to the living *Cercolabes* of South America.

Fam. 4. *Castoridæ*.—The best-known example of this family is the Beaver (*Castor fiber*). The distinctive peculiarities of the family are the possession of distinct clavicles, the possession of five toes to each foot, and the fact that the hinder feet are mostly webbed, adapting the animal to a semi-aquatic life.

The genus *Castor*, comprising the existing Beaver, and characterised by the possession of a flattened scaly tail, is represented by fossil species in the Miocene and Pliocene deposits of Europe. The *Castor spelæus* of the European cave-

deposits does not appear to be specifically separable from the existing Beaver (*Castor fiber*). The great *Trogontherium* (fig. 372) of the Post-Tertiary deposits of Europe, also appears to be generically inseparable from *Castor*. The *Castoroides Ohioensis* of the Post-Tertiary period of North America seems to be rightly referred to a separate genus. The only known species attained a comparatively gigantic size, reaching a length of about five feet. The *Chalicomys* of the European Miocene and Pliocene deposits appears to be nearly related to the Beavers; and the bone-caves of Brazil have yielded a species of *Myopotamus* nearly allied to the existing Coypu (*Myopotamus coypus*) of South America.

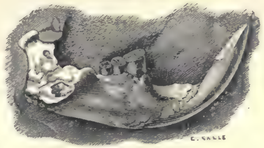


Fig. 372.—Jaw of *Trogontherium Cuvieri*. Post-Pliocene.

Fam. 5. *Muridæ*.—The fifth family of Rodents is that of the *Muridæ*, comprising the Rats, Mice, and Lemmings. In this family the tail is long, always thinly haired, sometimes naked and scaly. The lower incisors are narrow and pointed, and there are complete clavicles. The hind-feet are furnished with five toes, the fore-feet with four, together with a rudimentary pollex.

Remains of Rats and Mice have been obtained in the Miocene and Pliocene Tertiary of Europe, and the Post-Tertiary forms are in several cases very nearly if not altogether undistinguishable from existing forms. The genus *Cricetus*, comprising the existing Hamster, is represented in Post-Tertiary deposits by a form probably identical with the living *C. vulgaris*. The Lemmings (*Myodes*) are represented by at least one species in Post-Tertiary deposits in Britain, occurring after the Glacial period, and being contemporary with "palæolithic" man. The Voles or Campagnols (*Arvicola*) commence in the Pliocene, and are abundantly represented in Post-Tertiary deposits. The Post-Glacial deposits of Britain have yielded remains of the *Arvicola pratensis*, *A. agrestis*, and *A. amphibia*, the last of which (the well-known "Water-rat") occurs also in Præ-Glacial accumulations.

Fam. 6. *Dipodidæ*.—The sixth family of the Rodents, which is sufficiently important to need notice, is that of the *Dipodidæ* or Jerboas, mainly characterised by the disproportionate length of the hind-limbs as compared with the fore-limbs. The tail also is long and hairy, and there are complete clavicles.

Remains of a species of Jerboa (*Dipus*) have been discovered in Miocene deposits in France, but they are of no special importance.

Fam. 7. *Myoxidæ.*—The members of this family are commonly known as Dormice, and they are often included in the following family of the Squirrels and Marmots.

They resemble the Squirrels in most respects, but they have only four molars on each side of the upper jaw, whereas the latter possess five. Two species of *Myoxus* have been detected in the Upper Eocene (Gypseous series of Montmartre), and a third species has been determined from beds of Miocene age. Several species have been detected in Post-Tertiary deposits, of which the most remarkable is the comparatively gigantic *Myoxus Melitensis* of the Maltese Post-Pliocene.

Fam. 8. *Sciuridæ.*—This is the last family of Rodents which calls for any special mention, and it comprises the true Squirrels, the Flying Squirrels, and the Marmots.

The members of this family are distinguished by their pointed or compressed incisors and their tubercular molars, the upper jaw having five of the latter on each side, whilst the lower jaw has only four. The genus *Sciurus*, comprising the true Squirrels, is represented from the Eocene Tertiary upwards, but none of the fossil forms are of special interest. The genus *Arctomys*, comprising the Marmots, is represented in the Pliocene by a single species, and by several forms in the Post-Tertiary. The Pouched Marmots (*Spermophilus*), lastly, appear for the first time in the Miocene; and Britain possessed two species in times posterior to the Glacial period.

ORDER XI. CHEIROPTERA.—This order is undoubtedly "the most distinctly circumscribed and natural group" in the whole class of the *Mammalia*. In many respects, however, it would be advantageous to regard the *Cheiroptera* as a sub-order of the next order (namely the *Insectivora*), specially modified to lead an aerial life; just as the *Pinnigrada* are regarded as a mere section of the *Carnivora* specially modified to suit an aquatic life.

The *Cheiroptera* are essentially characterised by the fact that the anterior limbs are longer than the posterior, the digits of the fore-limb, with the exception of the pollex, being enormously elongated (fig. 373). These elongated fingers are united by an expanded membrane or "patagium," which is also extended between the fore and hind limbs and the sides of the body, and in many cases passes also between the hind-limbs and the tail. The patagium thus formed is naked, or nearly so, on both sides, and it serves for flight. Of the fingers

of the hand, the pollex, and sometimes the next finger as well, are unguiculate, or furnished with claws; but the other digits are destitute of nails. In the hind-limbs all the toes are unguiculate, and the hallux is not in any respect different from the other digits. Well-developed clavicles are always present, and the radius has no power of rotation upon the ulna. The mammary glands are two in number, and are placed upon the chest. There are teeth of three kinds, and the canines are always well developed. The molars are tuberculate or grooved in the frugivorous forms, and cuspidate in the insectivorous species. The ulna is sometimes quite rudimentary. The bones are not pneumatic.

Fig. 373.—Skeleton of Fox-bat (*Pteropus*)—after Owen.

The living Bats are divided into the two groups of the Frugivorous Bats, comprising the single family of the *Pteropidæ* (Fox-bats or Roussettes), and the Insectivorous Bats, comprising the three families of the *Vespertilionidæ*, the *Rhinolophidæ* (Horse-shoe Bats), and the *Phyllostomidæ* (Vampire Bats). The *Cheiroptera* are represented for the first time in the Eocene Tertiary of Europe, and that by a form very similar to the existing European Bats. The fossil in question is the *Vespertilio Parisiensis* (fig. 374) of the Gypseous series of Montmartre (Upper Eocene). Other species of small In-

sectivorous Bats (*Vespertilio*) have been discovered in Miocene, Pliocene, and Post-Tertiary deposits. The Horse-shoe Bats (*Rhinolophus*) have as yet only been discovered in cave-deposits. Lastly, the Vampire Bats are represented by no less than five species in the Post-Pliocene cave-deposits of Brazil, in which country is found the living *Phyllostoma spectrum*.

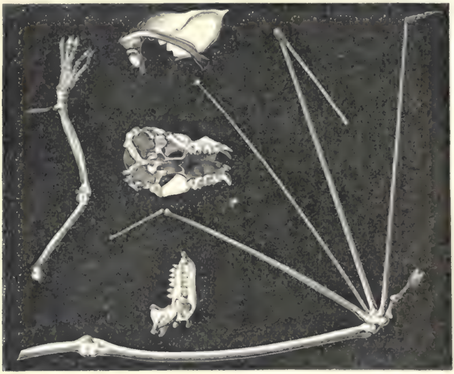


Fig. 374.—*Vespertilio Parisiensis*. Upper Eocene.

ORDER XII. INSECTIVORA.—The twelfth order of Mammals is that of the *Insectivora*, comprising a number of small Mammals which are very similar to the Rodents in many respects, but want the peculiar incisors of that order, and are likewise always furnished with clavicles.

In the *Insectivora*, all the three kinds of teeth are usually present, but the exact nature of the dentition varies considerably in different cases. The incisors and canines present little special, but the molars are always serrated with numerous, small, pointed eminences or cusps, adapted for crushing insects. With one exception, clavicles are always present in a complete form. All the feet are usually furnished with five toes; all the toes are furnished with claws; and the animal walks on the soles of the feet, or is plantigrade.

The earliest traces of Insectivorous Mammals are in the Eocene Tertiary (the *Spalacodon* of the Upper Eocene of Hordwell, discovered by Mr Flower). The order, however,

does not become well represented till we reach the Miocene period.

The three leading families of the *Insectivora* are the *Talpidæ* or Moles, the *Soricidæ* or Shrew-mice, and the *Erinaceidæ* or Hedgehogs.

Fam. 1. *Talpidæ*.—The body in this family is covered with hair; the feet are formed for digging and burrowing, and the toes are furnished with strong curved claws.

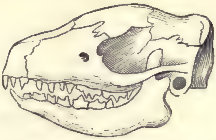


Fig. 375.—Insectivora. Skull of the common Hedgehog (*Erinaceus Europæus*).

The earliest remains of *Talpidæ* appear for the first time in the Miocene Tertiary; but they are of little importance. The common Mole (*Talpa Europæa*) occurs in Post-Pliocene deposits in Britain and on the Continent. Several genera (*Dimylus*, *Palæospalax*, *Geotrypus*, &c.) have been founded upon remains of Mole-like animals from the Miocene and later Tertiary deposits.

Fam. 2. *Soricidæ*.—The *Soricidæ* or Shrew-mice are distinguished by having the body covered with hair, and the feet not adapted for digging; whilst there are external ears, and the eyes are well developed. Of all the *Insectivora*, no division is more abundant or more widely distributed than that of the Shrew-mice. In general form and appearance the Shrews very closely resemble the true Mice (*Muridæ*) and the Dormice (*Myoxidæ*), but they are in reality widely different, and must not be confounded with them.

Remains of Shrews (belonging to the genera *Sorex*, *Mysarachne*, and *Plesiosorex*) have been discovered in the Miocene deposits of Europe. Several existing species (such as *Sorex araneus* and *S. fodiens*) occur in Post-Tertiary cave-deposits and ossiferous breccias. Lastly, the Desmans (*Mygale*) are represented from the Miocene Tertiary onwards.

Fam. 3. *Erinaceidæ*.—The last family of the *Insectivora* is that of the Hedgehogs, characterised by the fact that the upper part of the body is covered with prickly spines, the feet are not adapted for digging, and the animal has mostly the power of rolling itself into a ball at the approach of danger.

Several species of Hedgehog have been found in the fossil state, commencing in the Miocene Tertiary. The *Erinaceus fossilis* of the Post-Tertiary period, does not appear to be separable from the common species (*Erinaceus Europæus*).

CHAPTER XLII.

ORDERS OF MAMMALIA—Concluded.

QUADRUMANA AND BIMANA.

ORDER XIII. QUADRUMANA.—The thirteenth order of Mammals is that of the *Quadrumana*, comprising the Apes, Monkeys, Baboons, Lemurs, &c., characterised by the following points :—

The hallux (innermost toe of the hind-limb) is separated from the other toes, and is opposable to them, so that the hind-feet become prehensile hands. The pollex (innermost toe of the fore-limbs) may be wanting, but when present, it also is usually opposable to the other digits, so that the animal becomes truly *quadrumanous*, or four-handed.

The incisor teeth generally are $\frac{2-2}{2-2}$, and the molars $\frac{3-3}{3-3}$ with broad and tuberculate crowns. Perfect clavicles are present. The teats are two in number, and are pectoral in position.

The Quadrumana are divided by Owen into three very natural groups, separated from one another by their anatomical characters and by their geographical distribution as follows :—

STREPSIRHINA.

This section of the *Quadrumana* is characterised by the possession of twisted or curved nostrils, placed at the end of the snout. The incisor teeth are generally much modified, and are in number $\frac{3-3}{3-3}$ as a rule; the præmolars are $\frac{3-3}{3-3}$ or $\frac{2-2}{2-2}$, and the molars are tuberculate. The second digit of the hind-limb has a claw, and both fore and hind feet have five toes each, all the thumbs being generally opposable. In the true Lemurs, all the digits, except the second toe of the hind-feet, are furnished with nails.

This section is often called that of the *Prosimiæ*, and it includes several families, of which the Aye-Ayes, Pottos, and true Lemurs are the most important.

No member of the Strepsirhine division of the *Quadrumana* has as yet been discovered in the fossil condition. When,

however, those regions of the world have been properly explored in which these forms occur at the present day, we shall doubtless find extinct representatives of this group. The Strepsirhine Monkeys, namely, are at present confined to Madagascar, Western Africa, and the Indian Archipelago; and these regions are as yet almost unknown, palæontologically speaking.

PLATYRHINA.

The section of the Platyrhine Monkeys is exclusively confined to South America, and one of its leading characters is to be found in the almost universal possession of a prehensile tail; this being an adaptive character by which the animal is suited to the arboreal life which so many of the South American Mammals are forced to lead. There are neither cheek-pouches nor natal callosities, and there is an additional præmolar, and sometimes a molar less than in man and the Old World Monkeys. The nostrils are simple, wide apart, and placed nearly at the extremity of the snout. The præmolars are $\frac{3-3}{3-3}$ in number, and have blunt tubercles. The thumbs of the fore-hands are either wanting altogether, or, if present, are not opposable, though versatile.

The fossil remains of Platyrhine Monkeys are only known to occur in South America, to which country all the existing forms are confined. Here, in deposits of late Tertiary or Post-Tertiary age, have been found remains of Monkeys referable to the existing genera *Cebus*, *Callithrix*, and *Iacchus*, along with a large form which constitutes the extinct genus *Protopithecus*, and which is allied to the recent *Mycetes*.

CATARHINA.

The third and highest section of the *Quadrumana* is that of the *Catarhina* or Old World Monkeys. In this section the nostrils are oblique, and are placed close together, and the septum narium is narrow. The thumbs of all the feet are opposable, so that the animal is strictly quadrumanous. In *Colobus* alone the anterior thumbs (pollex) are wanting. The dental formula is the same as in man, viz.:—

$$i\,\frac{2-2}{2-2};\ c\,\frac{1-1}{1-1};\ pm\,\frac{2-2}{2-2};\ m\,\frac{3-3}{3-3} = 32.$$

The incisors, however, are projecting and prominent, and the canines—especially in the males—are large and pointed. Moreover, the teeth form an uneven series, interrupted by a

diastema or interval. The tail is never prehensile, and is sometimes absent. Cheek-pouches are often present, and the skin covering the *tubera ischii* is almost always callous and destitute of hair, constituting the so-called "natal callosities." With the single exception of a Monkey which inhabits the Rock of Gibraltar, all the *Catarhina* are natives of Africa and Asia.

The earliest traces of the Catarhine Monkeys (constituting the oldest known relics of the entire order of the *Quadrumana*) appear in the Eocene Tertiary; and they occur only in the Old World, so far as is yet known. The *Macacus eocænus* of the London Clay has now been referred to *Hyracotherium;* but the *Cœnopithecus lemuroides* of Rütimeyer, from deposits of Eocene age, appears to be an undoubted Monkey. *Cœnopithecus*, however, cannot be referred with any certainty to the

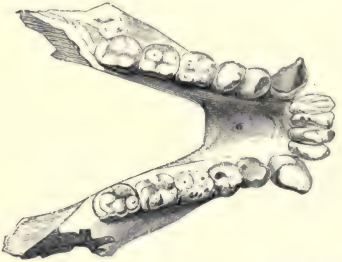


Fig. 376.—Lower jaw of *Pliopithecus* (*Pithecus*) *antiquus*. Miocene.

Catarhina, its most marked affinities being with the genus *Mycetes* on the one hand, and the *Lemuridæ* on the other. In the Miocene deposits of Greece occur the remains of a Macaque (*Mesopithecus Pentelici*); and in deposits of the same age in France have been found the remains upon which have been founded the genera *Pliopithecus* (fig. 376) and *Dryopithecus*. The former of these appears to have been most nearly allied to the recent genus *Semnopithecus*, in which case it must have possessed a tail and cheek-pouches. The latter appears to have been more nearly allied to the living Gibbons (*Hylobates*), in which case it must have been destitute of a tail and of cheek-pouches.

Besides the above, the Pliocene (or Miocene) deposits of India have yielded the remains of *Semnopithecus*, *Macacus*,

and a form allied to the Orang. The Pliocene deposits of France contain remains of the genera *Semnopithecus*, *Macacus*, and *Cercopithecus;* and a jaw of *Macacus* has been obtained from similar deposits in Essex.

ORDER XIV. BIMANA.—This, the last remaining order of the *Mammalia*, comprises Man (*Homo*) alone, and it will therefore require but little notice here, the peculiarities of Man's mental and physical structure properly belonging to other branches of science.

Zoologically, Man is distinguished from all other Mammals by his habitually erect posture and bipedal progression. The lower limbs are exclusively devoted to progression and to supporting the weight of the body. The anterior limbs are shorter than the posterior, and have nothing whatever to do with progression. The thumb is opposable, and the hands are prehensile, the fingers being provided with nails. The toes of the hind-limb are also furnished with nails, but the *hallux* is not opposable to the other digits, and the feet are therefore useless as organs of prehension. The foot is broad and plantigrade, and the whole sole is applied to the ground in walking.

The dentition consists of thirty-two teeth, and these form a nearly even and uninterrupted series, without any interval or diastema. The dental formula is—

$$i\,\frac{2-2}{2-2};\ \ c\,\frac{1-1}{1-1};\ \ pm\,\frac{2-2}{2-2};\ m\,\frac{3-3}{3-3} = 32.$$

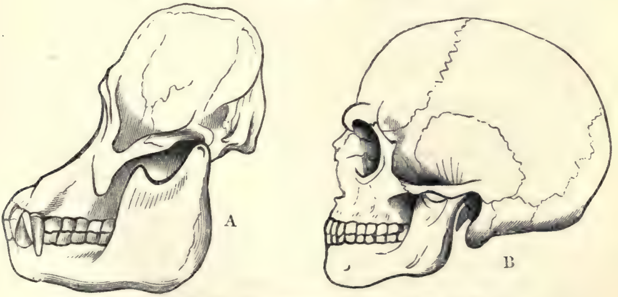


Fig. 377.—A, Skull of the Orang-outang. B, Skull of an adult European.

The brain is more largely developed and more abundantly furnished with large and deep convolutions than is the case with any other Mammal. The mammæ are pectoral, and the placenta is discoidal and deciduate.

Man is the only terrestrial Mammal in which the body is not provided with a covering of hair.

Palæontologically, there is little to be said about Man—or, rather, so much might be said on this subject that its discussion can only be properly taken up in a special treatise. Man appeared upon the earth, so far as we know, only in the last or Post-Tertiary period of Geology, and his remains, in the form of bones or implements of various kinds, have been detected in various Post-Tertiary accumulations, such as valley-gravels and cave-deposits. The chief facts as to the past existence of man which concern the palæontological student may be briefly stated as follows:—

1. Man unquestionably existed during the later portion of what Sir Charles Lyell has termed the "Post-Pliocene" period. In other words, Man's existence dates back to a time when several remarkable Mammals, to be afterwards mentioned, had not yet become extinct; but he does not date back to a time anterior to the present *Molluscan* fauna.

2. The antiquity of the so-called Post-Pliocene period is a matter which must be mainly settled by the evidence of Geology proper, and need not be discussed here.

3. The extinct Mammals with which man coexisted in Western Europe are mostly of large size, the most important being the Mammoth (*Elephas primigenius*), the Woolly Rhinoceros (*Rhinoceros tichorhinus*), the Cave-lion (*Felis spelæa*), the Cave-hyæna (*Hyæna spelæa*), and the Cave-bear (*Ursus spelæus*). We do not know the causes which led to the extinction of these Post-Pliocene Mammals; but we know that no Mammalian species has become extinct during the historical period.

4. The extinct Mammals with which man coexisted are referable in many cases to species which presumably required a very different climate to that now prevailing in Western Europe. How long a period, however, has been consumed in the bringing about of the climatic changes thus indicated we have no means of calculating with any approach to accuracy.

5. Some of the deposits in which the remains of man have been found associated with the bones of extinct Mammals, are such as to show incontestably that great changes in the physical geography and surface-configuration of Western Europe have taken place since the period of their accumulation. We have, however, no means at present of judging of the lapse of time thus indicated except by analogies and comparisons which may be disputed.

6. The human implements which are associated with the

remains of extinct Mammals, themselves bear evidence of an exceedingly barbarous condition of the human species. Post-Pliocene or "Palæolithic" Man was clearly unacquainted with the use of any of the metals. Not only so, but the workmanship of these ancient races was much inferior to that of the later tribes, who were also ignorant of the metals, and who also used nothing but weapons and tools of stone.

7. Lastly, it is only with the human remains of the Post-Pliocene period that the palæontologist proper has to deal. When we enter the "Recent" period, in which the remains of Man are associated with those of *existing species of Mammals*, we pass out of the region of pure palæontology into the domain of the Archæologist and the Ethnologist.

PART III.

PALÆOBOTANY

PALÆOBOTANY.

CHAPTER XLIII.

General Relations of Plants to Time.

The subject of Palæobotany or Palæophytology is one which is far too vast to be treated of in a work of this nature; whilst it is one which is of less importance to the general student than that of Palæozoology. For this reason, nothing further will be attempted here than to give the briefest and most elementary outline of the general distribution of plants in past time, to which will be added a short summary of the chief forms of vegetable life which characterise each of the great formations. The following table shows the leading groups into which the Vegetable Kingdom is divided:—

Divisions of the Vegetable Kingdom.

I. Cryptogamic Plants (Gr. *kruptos*, concealed; *gamos*, marriage), distinguished by having no distinct flowers or fruit. They include—

a. Thallogens.—Ex. Sea-weeds (*Algæ*), Lichens, Mushrooms.

b. Anogens.—Ex. Liverworts, Mosses.

c. Acrogens.—Ex. Club-mosses (*Lycopodiaceæ*), Ferns, Horse-tails (*Equisetaceæ*).

II. Phanerogamic Plants (Gr. *phaneros*, conspicuous; *gamos*, marriage), distinguished by having distinct flowers and seeds. They are divided into—

a. Endogens.—Ex. Grasses, Palms, Lilies. These have *endogenous* stems, showing no rings of growth, and the young plant possesses but a single seed-lobe or "cotyledon." Hence they are often called *Monocotyledons.*

b. Exogens.—Ex. Pines and Cycads, with most ordinary shrubs, trees, and flowering plants. The Pines and Cycads, with the fossil *Sigillariæ*, have the seed naked, and are hence called *Gymnosperms* (Gr. *gumnos*, naked; *sperma*, seed). Ordinary trees and shrubs, on the other hand, have the seed covered, and are therefore called *Angiosperms.* Both the Gymnosperms and Angiosperms have an *exogenous* mode of growth, with a true bark and annual rings of growth. The seed also possesses two seed-lobes or "cotyledons;" and they are therefore often spoken of as *Dicotyledons.*

The remains of Plants appear for the first time, so far as yet known, in the Lower Cambrian series (the *Eophyton* of the Fucoidal Sandstone of Sweden); and from this time onward they are never absent altogether from any of the great geological formations. The affinities of this earliest known plant are so dubious that it cannot be employed as proving the first appearance of any of the great groups of plants. The Upper Cambrian and Lower Silurian Rocks have yielded various remains of an unquestionable vegetable nature, but of doubtful affinities—referred, however, with more or less probability, to Sea-weeds ("Fucoids"). In the Upper Silurian Rocks have been detected various Sea-weeds (*Spirophyton*, &c.), the spore-cases of Lycopodiaceous plants (*Pachytheca*), *Lepidodendron*, and remains of the remarkable generalised type *Psilophyton*, which is in some respects intermediate between the *Lycopodiaceæ* (Club-mosses) and the Ferns. In the Devonian period—as we now know, from the researches of Dr Dawson of Montreal in particular—plants are very abundant, and belong to varied types. The great group of the Gymnospermous Exogens is here represented by remains of various Conifers (*Dadoxylon*, *Ormoxylon*, and *Prototaxites*). The Ferns are represented by numerous species, in many cases not far removed from types now in existence; and it is interesting to notice that Tree-ferns (*Psaronius* and *Caulopteris*) are not wanting amongst these. The *Lycopodiaceæ* or Club-mosses are represented in the Devonian Series by numerous remarkable types, such as *Lepidodendron*, *Lepidophloios*, *Cordaites*, and *Lycopodites*. The Sigillarioid plants, regarded by different authorities as being Coniferous, or Lycopodiaceous, or as being intermediate between the Acrogens and Gymnosperms—are represented by species of *Sigillaria* itself, with its *Stigmaria* roots. The Horse-tails or *Equisetaceæ* are represented by species of the remarkable genus *Calamites*. The genus *Antholithes*, commonly supposed to be the spike of fructification of some phanerogamic plant, and now known to bear the probably Gymnospermous fruit, *Cardiocarpon*—is represented by two species in the Devonian Rocks. Lastly, the Devonian formation of the State of New York has yielded the remains of an Angiospermous Exogen, which has been described by Dr Dawson, under the name of *Syringoxylon mirabile*.

We thus see, even from such an imperfect summary as the above, that we must abandon the old view that nothing like a general and varied flora existed in times anterior to the Coal-measures. We see that at a point of Palæozoic time as early as that represented by the Devonian formation, the earth exhibited a far from scanty vegetation, composed of true land-

plants, and embracing representatives of almost all the great groups of plants which at present grow upon its surface. Thus, we find in the Devonian Rocks representatives of the groups of the Horse-tails, Club-mosses, Ferns, and Gymnospermous and Angiospermous Exogens. We have, however, no certain representative of the great group of the Endogens, whilst the Angiospermous Exogens are known by a single genus only, represented by a single species. Upon the whole, therefore, the vegetation of the Devonian period is characterised by the predominance of Cryptogams and Gymnospermous Exogens.

Passing on to the Carboniferous period, we have to consider the largest and most varied of the Palæozoic floras, but one which is in most respects very similar to that of the Devonian period. Some Devonian genera of plants do not pass up into the over-lying formation, and some of the Carboniferous genera have not been recognised in the Devonian; whilst hardly any *species* are common to the two floras. Still, the general *facies* of the Carboniferous vegetation is much the same as that of the Devonian; and the same groups predominate in the former as in the latter, The predominant groups of plants in the Carboniferous Rocks are the Ferns (*Filices*), the Sigillarioids, the Lepidodendroids, and the Calamites, of which all except the Sigillarioids are certainly Cryptogams. Here, also, we have the first instance of the occurrence of a Fungus (*Archagaricon*). The *Coniferæ* are well represented by several genera (*Araucarioxylon*, *Dadoxylon*, &c.), but no remains of trees belonging to the Angiospermous Exogens have been as yet detected. There are, however, a few flowering plants (such as the Monocotyledonous *Pothocites* of the Scotch Carboniferous). Lastly, the Carboniferous Rocks have yielded remains of the genus *Nœggerathia*, referred by Brongniart to the peculiar Gymnospermous group of the *Cycadaceæ*, but regarded by others as belonging to the Ferns.

In the Permian period, the vegetation is nearly related to that of the Coal-measures. We have still numerous Ferns (*Neuropteris*, *Pecopteris*, *Sphenopteris*), Tree-ferns (*Psaronius*), the Lycopodiaceous *Lepidodendron*, and Calamites. The Conifers, also, are abundant, and belong to several genera. Some of the Conifers, however (as *Ullmania*), bear genuine cones, and the Sigillarioids, which are so characteristic of the Carboniferous period, have apparently altogether disappeared in the Permian.

With the Trias we commence the great series of Mesozoic deposits, and there is a marked change in the vegetation of this period as compared with that of the Carboniferous and Permian epochs. The *Lepidodendroids* and *Sigillarioids* have now com-

pletely disappeared. The Calamites of the Coal-measures are represented by true Horse-tails (*Equisetites*). Ferns and Conifers are still abundant, and some of the latter (*Voltzia*) are by no means unlike existing forms. Lastly, there is an abundance of remains of Cycadaceous plants (*Pterophyllum*, *Podozamites*, &c.)

The Jurassic and Lower Cretaceous deposits are similarly characterised by an abundance of Cycads, Ferns, and Conifers, the first of these in particular constituting a marked feature in the vegetation.

In the Upper Cretaceous period we have the first appearance, in any quantity, of ordinary Angiospermous Exogens, similar to those which predominate at the present day in the flora of temperate regions. Besides Ferns and Cycads more or less allied to Jurassic forms, we have now numerous Dicotyledonous trees, such as the Oak, Beech, Fig, Poplar, Walnut, Willow, Alder, &c., belonging to familiar genera now in existence. Here, also, we have the first appearance, so far as is certainly known, of the group of the Palms.

Of the vegetation of the Tertiary period, it is sufficient to remark here that now there is a marked predominance of Angiospermous Exogens and of Endogens as compared with Cryptogams and Gymnospermous Exogens. Not only is this the case, but many of the Tertiary plants approximate closely to existing forms, this approximation becoming more and more marked as we recede from the Eocene and approach the Recent period.

Before closing this brief review of the succession of plants upon the globe, it may be well to notice shortly a generalisation which was long since made by M. Adolphe Brongniart. This distinguished observer, in dividing the series of stratified deposits in accordance with the fossil plants contained in them, named the Palæozoic period the "Age of Acrogens," the Secondary period (exclusive of the Cretaceous) the "Age of Gymnosperms," and the Cretaceous and Tertiary periods the "Age of Angiosperms." This generalisation, though still expressing a general truth, can only be accepted with considerable reservation. Gymnosperms, and even Angiosperms, are not unknown in the Palæozoic period; and if the Sigillarioids should be referred to the former group of plants, then the later Palæozoic period would have as good claim to be called the "Age of Gymnosperms" as the Secondary period. Again, as pointed out by Sir Charles Lyell, the Lower and Upper Cretaceous floras differ from one another in the most striking manner, the Lower Cretaceous agreeing in this respect with the Jurassic

series, whilst the Upper Cretaceous series is linked on by its plants to the Tertiary formations. The line, therefore, between the Age of Gymnosperms and the Age of Angiosperms must be drawn between the Lower and Upper Cretaceous, and not at the base of the Cretaceous series.

CHAPTER XLIV.

PRE-CARBONIFEROUS FLORAS.

CAMBRIAN PLANTS.—The Laurentian and Huronian deposits have as yet yielded no remains of plants; but the occurrence of graphite in large quantity in the former of these would strongly support the view that the Laurentian period was not without an abundant vegetation. The Lower Cambrian Rocks have yielded many so-called "fucoids;" but these are almost invariably to be referred to the tracks and burrows of marine worms. The only apparently unequivocal plant of the Lower Cambrian period is the *Eophyton* (fig. 378) of the "Fucoidal Sandstone" of Sweden.

The singular fossils referred to this genus consist of straight, furrowed, and striated stems, which can hardly be anything else than the remains of plants. The affinities, however, of these ancient fossils are quite undetermined, except that it seems pretty certain that they cannot be referred to the *Algæ.*

In the Upper Cambrian Rocks (Potsdam Sandstone) of North America occur various so-called "Fucoids" (*Palæophycus*, &c.) The true nature of these, however, is in many cases very doubtful, and it is questionable if any of them can really be regarded as plants.

Here, also, we may briefly consider certain remains discovered by the author in the Skiddaw Slates of the North of England, a formation which is probably referable to the Upper Cambrian, but which good authorities regard as belonging to the Lower Silurian series. The remains in question were originally referred provisionally to the genera *Buthotrephis* and *Eophyton*, and the fossils which led to the former determination appear to be indubitable plants. They are thus described by Dr Dawson in a note communicated to the author:—

1. *Buthotrephis Harknessii.*—This consists of what have been cylindrical branches, given off from a central stem, and producing a few branchlets in the manner of *Pinnularia.* Under the microscope the branches show a

vesicular structure; but this I believe to have been produced by the weathering out of minute globular concretions, probably of calcareous matter. The appearances are rather those of roots or slender herbaceous stems than of Algæ. If found in the Coal-measures it would probably be regarded as an obscure *Pinnularia*.

2. *Buthotrephis radiatus*.—This shows radiating branchlets or leaves, with the same vesicular structure as the preceding, and having some resemblance to the whorls of *Annularia*, though without any midrib.

It is quite possible that both of the above may belong to the same species. If a land-plant, allied to *Annularia*, the first may represent the roots or subaquatic stems, and the second its whorls of leaves. If an Alga, the first may represent branching fronds, and the latter the fructification. Under the former supposition, they may be compared with *Annularia laxa* of the Devonian, and the radiating root-like bodies associated with it.—(Dawson, 'Report on Devonian Flora.') Under the supposition that the plants are Algæ, they may be compared with *Sphærococcites Schurtzanus* of Goeppert, from the Lower Silurian (Etage D.) of Bohemia, though they do not come under the technical definition of Sternberg's genus *Sphærococcites*.

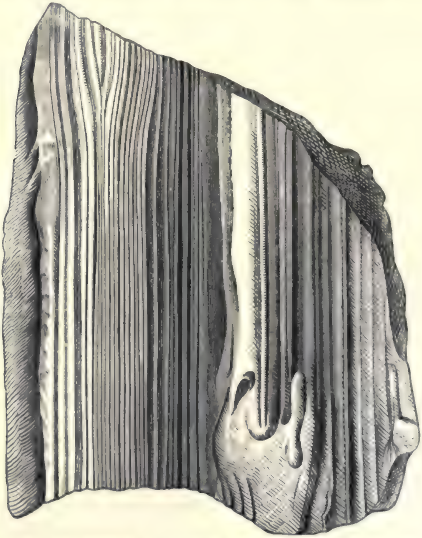


Fig. 378.—Fragment of *Eophyton Linneanum*. Lower Cambrian.

SILURIAN PLANTS.—The remains of plants in the Silurian series are few in number and require little consideration. In

the Lower Silurian Rocks no undoubted traces of land-plants have hitherto been detected. The deposits of this period, however, have yielded numerous fossils which have been referred to "Fucoids," under the generic titles of *Palæophycus*, *Licrophycus*, *Buthotrephis*, *Phytopsis*, *Sphenothallus*, &c. Some of these appear to be nothing more than the tracks of Annelides. Others appear to be unquestionable plants; but nothing positive can be stated as to their affinities. They may be *Algæ*, or they may belong to plants higher in the vegetable scale. Subjoined is an illustration of a characteristic Canadian species described by Mr Billings (fig. 379).

Fig. 379.—*Licrophycus Ottawaensis*, a "Fucoid" from the Trenton Limestone (Lower Silurian) of Canada. After Billings.

In the Upper Silurian Rocks are also numerous remains of "Fucoids" (*Arthrophycus*, *Dictuolites*, *Chondrites*, *Spirophyton*, &c.), which do not differ in any important point from those of the inferior division. Some of these can hardly be anything but true plants, and would certainly seem to be the remains of

genuine Sea-weeds. Besides these problematical fossils, however, the Upper Silurian Rocks have been shown to contain the remains of genuine land-plants. Thus, remains of the Lycopodiaceous genus *Lepidodendron* (*Sagenaria*) have been discovered in the Upper Silurian of Germany and Bohemia. At the summit of the Upper Silurian series in Britain have been detected numerous seed-vessels or "sporangia" referred by Hooker to a Lycopodiaceous plant under the generic title of *Pachytheca*. Lastly, the Upper Silurian of North America has yielded remains of the characteristic Devonian genus *Psilophyton*, which will be described immediately.

Devonian Plants.—The plants of the Devonian period belong to the groups of the *Equisetaceæ* (Horse-tails), *Lycopodiaceæ* (Club-mosses), *Filices* (Ferns), Sigillarioids, and *Coniferæ*—the whole constituting an abundant terrestrial vegetation. Besides the above, however—as already mentioned—the remains of a true Angiospermous Exogen have in one instance been detected in Devonian strata (Dawson).

The *Equisetaceæ* are represented by species of the remarkable genus *Calamites*, the characters of which will be briefly spoken of when treating of the Coal-plants.

The *Lycopodiaceæ* are represented by the genera *Lepidodendron*, *Lycopodites*, *Leptophlæum*, *Lepidophloios*, *Cordaites*, and *Psilophyton*. The Lepidodendroids will be shortly discussed under the head of the plants of the Carboniferous series; but *Cordaites* and *Psilophyton* merit special notice here. The genus *Cordaites* is common both to the Devonian and the Carboniferous formations, and includes broad, striated, parallel-veined leaves, which are extremely abundant in certain beds. They possess broad clasping bases, and may attain a length of a foot and a breadth of as much as three inches. Their affinities are disputed; but they are regarded by Dr Dawson as referable to some Lycopodiaceous plant.

The genus *Psilophyton* of Dawson (fig. 380) commences its existence in the Upper Silurian Rocks; but it is characteristically Devonian, and is not known to be represented in the Carboniferous period. The following is given by Dr Dawson as the definition of the genus :—

"Stems branching dichotomously, and covered with interrupted ridges. Leaves rudimentary, or short, rigid, and pointed; in barren stems, numerous and spirally arranged; in fertile stems and branchlets, sparsely scattered or absent; in decorticated specimens represented by minute punctate scars. Young branches circinate; rhizomata cylindrical, covered with hairs or ramenta, and having circular areoles irregularly disposed,

Fig 380.—*Psilophyton princeps* (Dawson). *a* Rhizome; *b* Stem; *c* Termination of a branch; *d* Vernation; *e* Fructification,—all of the natural size; *g* Areole of rhizome enlarged; *h* Restoration of the plant, reduced. Devonian of Canada.

giving origin to slender cylindrical rootlets. Internal structure—an axis of scalariform vessels, surrounded by a cylinder of parenchymatous cells, and by an outer cylinder of elongated woody cells. Fructification consisting of naked oval spore-cases, borne usually in pairs on slender curved pedicles, either lateral or terminal."

Species of *Psilophyton* occur all through the Devonian series of North America, and they are also not wanting in the Old Red Sandstone of Britain. The genus is regarded by Dr Dawson as comprising "synthetic or generalised plants, having rhizomata resembling those of some ferns, stems having the structure of *Lycopodium*, and rudimentary leaves also resembling those of *Lycopodiaceæ*, branchlets with circinate vernation like that of Ferns, and sporangia of a type quite peculiar to themselves."

The Ferns of the Devonian period are very numerous, and upon the whole present a close resemblance to those of the Carboniferous period. The smaller forms are represented by such genera as *Cyclopteris*, *Neuropteris*, *Sphenopteris*, *Alethopteris*, *Pecopteris*, &c. Besides these, however, there occur the trunks of large Tree-ferns, which are referred to the genera *Psaronius*, *Caulopteris*, and *Protopteris*. Subjoined is an illustration of a Fern from the Devonian of Europe (fig. 381).

The *Sigillarioids* of the Devonian series comprise forms referable to the well-known genera *Sigillaria* (with *Stigmaria*) and *Calamodendron*; though the affinities of the last are not well understood. The characters of these genera will be noticed in treating of the plants of the Carboniferous series.

The *Coniferæ* of the Devonian Rocks belong to the genera *Dadoxylon*, *Ormoxylon*, and *Prototaxites*. All of these are exogenous trees with concentric rings of growth, and the two former are undoubtedly Coniferous, as their woody tissue exhibits discs under the microscope. *Prototaxites*, unlike the preceding, occurs in the Lower Devonian series, and is therefore the oldest Exogenous tree at present known to us. The woody fibres do not exhibit punctations, and there is therefore some doubt as to the exact position of this genus.

In addition to the preceding forms, the Devonian Rocks have yielded examples of the fossils known as *Sternbergia*, *Cyperites*, *Asterophyllites*, *Annularia*, *Pinnularia*, *Cardiocarpon*, and *Trigonocarpon*. Of these, the genus *Sternbergia* comprises cylindrical, transversely-marked fossils, which are now known to be nothing more than the casts of the pith-cylinders of other plants. They seem chiefly to belong to Conifers of the genus *Dadoxylon*, but they are referable also to *Sigillaria*, and even

to *Lepidodendron.* When the plant to which they belong is itself preserved, there is no difficulty in recognising the true

Fig. 381.—*Sphenopteris laxus.* Devonian.

nature of the *Sternbergiæ;* but when the outer wood has been denuded, it becomes almost impossible to determine to what plant they may have belonged. The genus *Cyperites* comprises elongated linear leaves, which appear truly to be the leaves of *Sigillariæ.* The genus *Asterophyllites* (fig. 382) comprises elegant plants with ribbed and jointed stems. The joints of the stems give off verticils of leaves, or branchlets bearing whorls of leaves, which are narrow, elongated, and furnished with a single midrib. This genus is not only found in the Devonian Series, but is commonly represented in the Coal-measures, to which the species here figured belongs.

The genus *Annularia* comprises plants which are of doubtful affinities, but which possessed slender stems bearing at intervals whorls of leaves. The *Annulariæ* appear to have been

floating plants, and they occur in both the Devonian and Carboniferous formations.

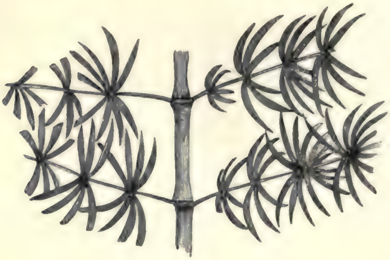


Fig. 382.—*Asterophyllites foliosus.* Coal-measures. (After Lindley and Hutton.)

The fossils known as *Pinnulariæ* are slender stem-like bodies, with a smooth or striate surface, producing at right angles long slender branchlets. The genus *Pinnularia* is regarded by Dawson as being founded upon the roots of other plants, such as *Asterophyllites* or *Calamites.*

Lastly, we find in the Devonian Rocks the little fruits known as *Cardiocarpon* and *Trigonocarpon,* which are so abundant in the Coal-measures. The *Cardiocarpa* appear mostly to have been winged achenes or "samaras;" but it is not altogether certain by what plants they were produced. It is now known, however, that the so-called *Antholithes* consists of a spike, bearing *Cardiocarpa* protected by bracts; and there is a considerable probability that they were produced by Sigillarioid trees. *Trigonocarpon* (fig. 383) comprises nut-like fruits, often of considerable size, and commonly three- or six- angled. The exterior of the fruit was probably fleshy, and well-preserved specimens show the integuments, and the internal cavity at one time filled by the albumen and embryo. *Trigonocarpon* is probably the fruit of a Conifer, and it shows a decided resemblance to the solitary fruit of the existing Taxoid genus, *Salisburia.* Possibly, however, Dr Dawson is correct in his conjecture that most of the *Trigonocarpa* belonged really to Sigillarioid plants.

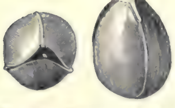


Fig. 383.—*Trigonocarpon ovatum.* Coal-measures. (After Lindley and Hutton.)

CHAPTER XLV.

THE CARBONIFEROUS AND PERMIAN FLORAS.

CARBONIFEROUS PLANTS.—The most extensive and the best known of the Palæozoic Floras is that which flourished during the Carboniferous period. At this time were formed those vast accumulations of vegetable matter which we know as *coal;* and much of our information as to the Carboniferous plants is due to the value of coal, and to the vigour with which coal-mining has been prosecuted.

Coal consists of nearly pure carbon, with varying proportions of hydrogen and oxygen and a small quantity of mineral matter. The following are the conclusions arrived at by Dr Dawson as to the minute structure of coal:— 1. The so-called "mineral charcoal" or "mother coal" consists chiefly of "bast-tissue" or of elongated cells derived from the inner bark of *Sigillariæ* and *Lepidodendra.* 2. Besides the above, the mineral charcoal contains in many instances scalariform tissue derived from Ferns, *Sigillariæ*, *Lepidodendra*, &c. 3. The coarse and laminated portions of the coal are made up of vascular bundles, derived apparently in the main from Ferns, along with other vegetable fragments, and in some cases, though not to a great extent, the sporangia of some of the Carboniferous Cryptogams. 4. In many parts of the coal occur discigerous or punctated woody fibres, belonging to *Dadoxylon*, *Sigillaria*, and *Calamodendron.* 5. A considerable portion of the coal is made up of "epidermal tissue," which is "a dense cellular tissue representing the outer integuments of various leaves, herbaceous stems, and fruits." 6. The layers of bright shining coal are composed of the flattened stems, and chiefly of the bark, of *Sigillariæ* and other trees. 7. Some layers of coal are occasionally composed mainly of the compressed leaves of *Cordaites.* 8. Sporangia are often present in coal; but they rarely exist in such a proportion as to any extent actually to form the coal themselves.

As has been already observed, the types of plants which are found in the Carboniferous Rocks are to a great extent identical with those which composed the Devonian flora. *Specifically*, however, the coal-plants are almost always distinct from the Devonian forms. The number of plants already known to have existed during the Carboniferous period is so great, that nothing more can be done here than to draw the attention of the student to some of the more important and characteristic types.

a. Filices. — The Ferns of the Carboniferous period are extremely numerous, and include both herbaceous forms like the majority of existing species, and arborescent forms similar to the living Tree-ferns of New Zealand. The latter belong to the genera *Psaronius*, *Caulopteris*, and *Palæopteris*, of which the two former occur in the older Devonian period. Of the

smaller ferns, the genera *Sphenopteris*, *Pecopteris*, *Alethopteris*, *Odontopteris*, *Neuropteris*, *Hymenophyllites*, and *Cyclopteris* may be mentioned as the most important and widely distributed. In the genus *Neuropteris* (fig. 384) the midrib of the leaflets is

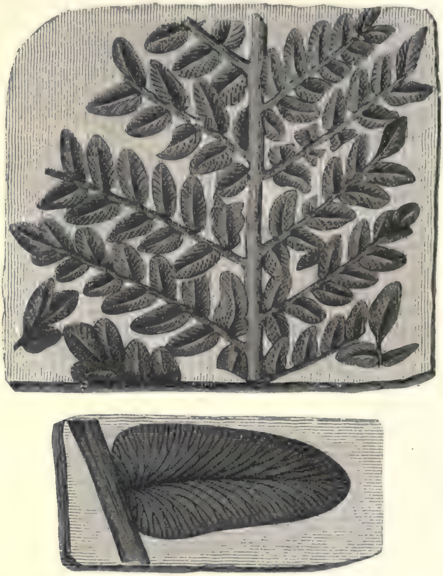


Fig. 384.—*Neuropteris heterophylla*. Coal-measures of Europe. The lower figure shows a single leaflet enlarged.

evanescent, either not distinct, or disappearing towards the apex. Species of this genus are found in the Coal-formation over almost the whole world. In *Alethopteris* the leaflets are attached by their bases to the stem and to one another, and are provided with a very distinct midrib from which the veins are given off nearly at right angles. The commonest species is the cosmopolitan *Alethopteris* (*Pecopteris*) *lonchitica*, which nearly resembles the living Brackens (*Pteris aquilina*). Nearly allied to *Alethopteris* is the genus *Pecopteris*, which includes a

large number of characteristic Carboniferous species. In *Odontopteris* (fig. 385) the frond is pinnate, the leaflets being attached by their entire bases, and the veins are generally given off from the base. The species here figured is a widely-distributed one, occurring in both Europe and North America.

Fig. 385.—*Odontopteris Schlotheimii.* Carboniferous of Europe and North America.

In the genus *Sphenopteris*, the leaflets are narrow towards their bases, often assuming a wedge-like form, the nervures dividing in a pinnate manner from the base.

Lastly, in the genus *Hymenophyllites* the frond exhibits a general resemblance to *Sphenopteris*, but the margin is divided into lobes, into each of which a single nervure is continued.

b. Calamites.—Amongst the commonest and most characteristic of the plants of the Carboniferous period are the striated fossils which are known as *Calamites*. Long as these have been known, and carefully as they have been studied, there is still no unanimity of opinion as to the affinities of these plants. The prevalent modern view, however, is that Calamites are truly referable to the *Equisetaceæ*, and that they may be regarded as gigantic Horse-tails—though they differ in many respects from any existing forms. The *Calamites* were "slender, ribbed, and jointed externally, and from the joints there proceeded, in some of the species, long, narrow, simple branchlets; and, in others, branches bearing whorls of small branchlets or rudimentary leaves. The stem was hollow, with thin transverse floors or diaphragms at the joints, and it

had no true wood and bark, but only a thin external shell of fibres and scalariform vessels. The *Calamites* grew in dense

Fig. 386.—*Calamites cannæformis*. Carboniferous of Europe and North America.

brakes on the sandy and muddy flats, subject to inundation, or perhaps even in the water, and they had the power of budding out from the base of the stem, so as to form clumps

of plants, and also of securing their foot-hold by numerous cord-like roots proceeding from various heights on the lower part of the stem. The fruit was a long cone or spike, bearing spore-cases under scales" (Dawson, Acadian Geology, p. 441). Besides the true *Calamites*, the Carboniferous Rocks have also yielded the remains of the genus *Equisetites*, which differed from the *Calamites*, and agrees with the existing Horse-tails in having sheaths at the joints.

Calamites often attain a comparatively gigantic size—twenty feet or more in length; and though they generally occur as prostrate and flattened stems, they are not uncommonly found in an erect and uncompressed condition, standing as they grew. The fossils known as *Asterophyllites* have been referred to *Calamites*, of which they were at one time supposed to constitute the foliage; but this opinion has been shown to be probably incorrect.

c. Calamodendron.—A good deal of the confusion which has prevailed as to the true nature of *Calamites* appears to have arisen out of the problematic fossils now generally referred to the genus *Calamodendron*. As ordinarily found, *Calamodendra* present themselves in the form of jointed and longitudinally-ribbed cylindrical stems, which are hardly separable from *Calamites*, except that they show no "areoles," or points whence leaves or branchlets have been given off. From the examination, however, of complete specimens, it has been shown that *Calamodendron*, as thus constituted, is really nothing more than the cast of the pith or medullary cavity of a complex woody stem, thus resembling in its nature the fossils known as *Sternbergia*. Round the internal axis thus constituted there is found in perfect examples a thick woody envelope, composed of ligneous wedges arranged concentrically and separated by intervening tracts of cellular tissue (or "medullary rays"). The external surface of the stem is not known, but the woody wedges are stated to consist of "elongated cells, and porous, discigerous, or pseudo-scalariform tissue." The affinities of *Calamodendron* are uncertain. It is regarded by different authorities as belonging to the Gymnospermous Exogens or to the Acrogens, or as a connecting form between these groups. In any case, it is necessary to distinguish very carefully between *Calamodendron* and *Calamites*, the latter being clearly separated by the absence of a woody envelope, and the presence of whorled leaves or branchlets at the articulations of the stem.

d. Lepidodendroids.—Under this head we have to consider the genera *Lepidodendron* and *Lepidophloios*, generally regarded

as gigantic extinct members of the Club-moss family (*Lycopodiaceæ*). The genus *Lepidodendron* (fig. 387) comprises nume-

Fig. 387.—*Lepidodendron Sternbergii*. Carboniferous.

rous large arborescent plants, which attain their maximum in the Carboniferous period, but which appear to commence in the Upper Silurian, and are well represented in the Devonian. The trunk in some cases reached a length of fifty feet or more,

and the branches are given off in a regular, bifurcating manner. The bark is marked with numerous rhombic or oval scars, arranged in quincunx order, and indicating the points where leaves were formerly attached. The branches were covered with slender, pointed leaves, closely crowded together; and the fructification was carried at the ends of the branches in the form of cones or spikes. These cones have generally been described under the name of *Lepidostrobi;* and they consist of a central axis, surrounded by imbricated scales or bracts, each of which supports a sporangium or spore-case.

In internal structure, *Lepidodendron* possesses a large central pith, surrounded by a continuous sheath of scalariform vessels. Outside this, again, is a thick bark, composed mainly of elongated fibres or "bast-tissue," with a thin dense outer rind.

The genera, or sub-genera, *Sagenaria*, *Knorria*, and *Aspidiaria*, are properly to be referred to *Lepidodendron*. The genus *Lepidophloios*, however, is represented in both in Devonian and Carboniferous Rocks by forms which are generically distinct from *Lepidodendron*. The genus includes Lycopodiaceous trees which have "thick branches, transversely elongated leaf-scars, each with three vascular points, and placed on elevated or scale-like protuberances, long one-nerved leaves, and large lateral strobiles in vertical rows or spirally disposed" (Dawson).

e. Sigillarioids.—The three chief genera included under this head are *Sigillaria*, *Rhytidolepis*, and *Favularia*, of which the first is the most important. The Sigillarioids commence their existence, so far as known, in the Devonian period, but they attain their maximum in the Carboniferous; and—unlike the Lepidodendroids—they are not known to occur in the Permian period. They are comparatively gigantic in size, often attaining a height of from thirty to fifty feet or more; but though abundant and well preserved, great divergence of opinion prevails as to their true affinities. The *name* of Sigillarioids (Lat. *sigilla*, little seals or images) is derived from the fact that the bark is marked with seal-like impressions or leaf-scars (fig. 388).

According to Dawson, *Sigillaria* proper is distinguished by its strong ribs, "which are usually much broader than the oval or elliptical tripunctate areoles, and are striated longitudinally." The stem consists of a central pith, which is transversely partitioned, as in the so-called *Sternbergiæ*. The pith is surrounded by a woody cylinder, consisting of ligneous wedges, composed of punctated (discigerous) and scalariform

vessels, and separated by medullary rays. Outside the woody axis is an inner bark composed of long durable fibres of "bast-tissue," the whole surrounded by a thick outer bark of dense cellular tissue. "The trunk when old lost its regular ribs and scars, owing to expansion, and became furrowed like that of an Exogenous tree." The roots, as will be seen immediately, constitute the fossils known as *Stigmaria*. The

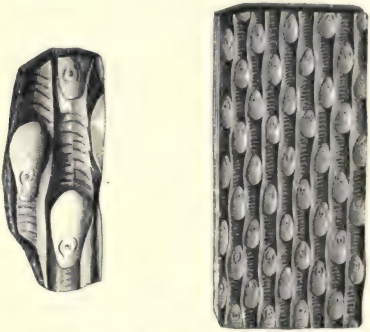


Fig. 388.—Fragment of *Sigillaria Græseri*. The left-hand figure shows a small portion enlarged. Carboniferous.

leaves are believed to be the so-called *Cyperites*, long, narrow, rigid, and two- or three- nerved. The fruits are supposed to be *Trigonocarpa*, "borne in racemes on the upper part of the stem." Upon the whole, Dr Dawson is disposed to adopt the view, originally put forth by Brongniart, that the *Sigillariæ* find their nearest living allies in the Cycads, and that if not actually referable to the Gymnospermous Exogens, they may be intermediate between these and the higher Acrogens.

Mr Carruthers, on the other hand, describes *Sigillaria* as consisting of a central cellular pith or medulla, surrounded by a sheath consisting wholly of scalariform vessels, the whole enveloped in an external cortical mass of cellular tissue. The medullary sheath is perforated by meshes for the passage outwards of the vascular bundles which go to the axial appendages (the leaves and branches); but there are no true medullary rays. Upon these grounds, Mr Carruthers decides against the view that *Sigillaria* is a Gymnospermous Exogen, and he regards it as Cryptogamic and Lycopodiaceous. He also dis-

credits the assertion that discigerous tissue is present, and describes the fruit as consisting of cones or strobiles.

Leaving the botanical position of *Sigillaria* thus undecided, we find that it is now almost universally conceded that the fossils originally described under the name of *Stigmaria* are the *roots* of *Sigillaria*, the actual connection between the two having been in numerous instances demonstrated in an unmistakable manner. The *Stigmariæ* (fig. 389) ordinarily present themselves in the form of long, compressed or rounded

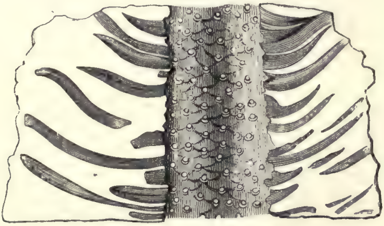


Fig. 389.—*Stigmaria ficoides*. Quarter natural size. Carboniferous.

fragments, the external surface of which is covered with rounded pits or shallow tubercles, each of which has a little pit or depression in its centre. From each of these pits there proceeds, in perfect examples, a long cylindrical rootlet; but in many cases these have altogether disappeared. In its internal structure, *Stigmaria* exhibits a central pith surrounded by a sheath of scalariform vessels, the whole enclosed in a cellular envelope. The *Stigmariæ* are generally found ramifying in the "underclay," which forms the floor of a bed of coal, and which represents the ancient soil upon which the *Sigillariæ* grew.

Of the remaining genera of the Sigillarioids, *Rhytidolepis* is the most important. It is characterised by the possession of large, hexagonal, tripunctate areoles, and narrow, often transversely striate ribs. In *Favularia*, lastly, the smaller branches were destitute of ribs, with elliptical, spirally-disposed areoles. The stem branched dichotomously—like that of a *Lepidodendron*—and the leaves were broad, with numerous parallel veins, approximating to the leaves of *Cordaites*.

f. Coniferæ.—True Conifers have long been known to occur in the Carboniferous Rocks. They belong to the genera *Dadoxylon*, *Palæoxylon*, *Araucarioxylon*, and *Pinites*. They

are recognised by the great size and concentric rings of their prostrate, rarely erect trunks, and by the fact that the microscope exhibits punctated fibres in their wood. Their fruit is unknown, unless, as is very probable, it is constituted by the so-called *Trigonocarpa*. If this be the case, the Carboniferous Conifers must have been "Taxoid," resembling the recent Yews in producing berries instead of true cones. The so-called *Sternbergiæ*, as has been already pointed out, are "pith-cylinders," or, in other words, casts of the pith, of *Dadoxylon*. They appear, however, to belong also to *Sigillaria* and *Lepidophloios*.

g. Cycadaceæ. — The peculiar group of Gymnospermous Exogens represented at the present day by the Cycads is not known with certainty to be represented in the Carboniferous Rocks. *Nœggerathia* has been referred here, and the Cycadaceous genus *Pterophyllum* has also been alleged to occur. Brongniart has also conjectured that the *Sigillarioids* are in reality most nearly allied to the *Cycadaceæ ;* and this opinion is supported by other high authorities.

h. Angiospermous Exogens.—The occurrence of true Angiosperms in the Carboniferous period is very doubtful. No Exogenous wood which is not Coniferous has been as yet detected. The fossil known as *Antholithes*, which was at one time conjectured to be possibly the infloresence of an Angiosperm, has now been shown to be really a raceme bearing the fruit termed *Cardiocarpon ;* and it remains uncertain to what plant this really belongs.

i. Monocotyledons. — The occurrence of Endogens in the Coal-formation is also attended with some uncertainty. The genus *Nœggerathia* has sometimes been referred to the Palms, and the same group has been asserted to be represented by species of *Palmacites*. The only apparently unequivocal proof of the occurrence of Carboniferous Endogens is, however, afforded by the so-called *Pothocites*, which appears to have been the spadix of an Aroideous plant.

PERMIAN PLANTS.—The Permian Flora is, upon the whole, very nearly allied to that of the Coal-measures, though the Permian species are mostly distinct, and there are some new genera. Thus, we find species of *Lepidodendron*, *Calamites*, *Equisetites*, *Asterophyllites*, *Annularia*, &c.—all genera which are highly characteristic of the Carboniferous period. On the other hand, the Sigillarioids of the Coal appear to have finally passed away with the close of the Carboniferous period.

Ferns are abundant in the Permian Rocks, and belong for the most part to the well-known Carboniferous genera *Alethop-*

teris, *Neuropteris*, *Sphenopteris*, and *Pecopteris*. There are also Tree-ferns referable to the genus *Psaronius*. The singular

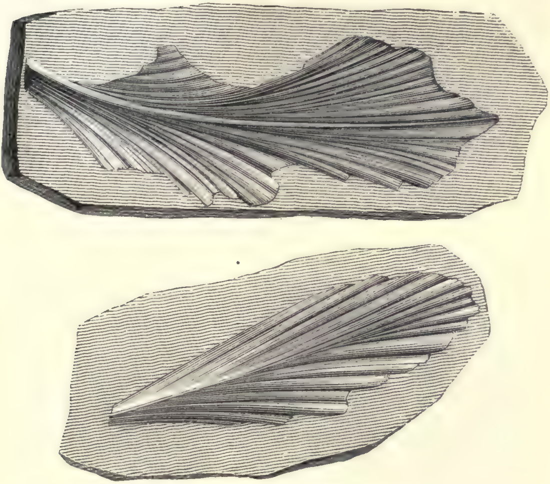


Fig. 390.—*Næggerathia expansa*. Permian.

genus *Næggerathia* (fig. 390) is also represented in the Permian Rocks.

Fig. 391.—*Walchia piniformis*; *a* Branch; *b* Twig. From the Permian of Saxony. (After Gutbier.)

The Conifers of the Permian period are numerous, and

belong in part to Carboniferous genera. A characteristic genus, however, is *Walchia* (fig. 391), distinguished by its lax short leaves. This genus, though not exclusively Permian, is mainly so, the best-known species being the *W. piniformis*. Here, also, we meet with Conifers which produce true cones, and which differ, therefore, in an important respect from the Taxoid Conifers of the Coal-measures. One of the most characteristic of these is the *Ullmania selaginoides*, which occurs in the Magnesian Limestone of Durham, the Middle Permian of Westmorland, and the "Kupfer-schiefer" of Germany.

CHAPTER XLVI.

FLORAS OF THE SECONDARY AND TERTIARY PERIODS.

TRIASSIC PLANTS. — With the Trias we commence what has been aptly termed the "Age of Cycads," from the predominance of the plants of this group in the Mesozoic vegetation. The Cycads are a group of Gymnospermous Exogens, the form and habit of growth of which present considerable resemblance to those of young Palms (fig. 392). The trunk is

Fig. 392.—*Zamia spiralis*, a living Cycad. Australia.

unbranched, often shortened, and bearing a crown of pinnate fronds. The leaves are usually "circinate"—that is, they unroll in expanding, like the fronds of Ferns. The ovules are borne upon the edge of altered leaves, or are carried on the scales of a cone. All the existing species of Cycads are

natives of warm countries, occurring in South America, the West Indies, Japan, Australia, Southern Asia, and South Africa. As has been already remarked, the occurrence of genuine Cycads in the Carboniferous vegetation has not been demonstrated, and the same holds good of all the Palæozoic floras. True Cycads, therefore, so far as known, make their first appearance in the Trias, at the commencement of the Mesozoic period, where they are represented by the genera *Pterophyllum*, *Zamites*, and *Podozamites*. Cycads continue to be abundantly represented throughout the whole Mesozoic series; but they have only been detected by a single dubious example in strata of Tertiary age. The name "Age of Cycads," as applied to the Secondary epoch, is, therefore, from a botanical point of view, an exceedingly appropriate one.

Besides Cycads, the Triassic Rocks have yielded the remains of Ferns, *Equisetites*, Calamites, and Conifers. The Ferns belong mostly to the genera *Neuropteris*, *Pecopteris*, *Acrostichites*, *Crematopteris*, *Cyclopteris*, and *Anomopteris*. A characteristic species of the first of these is figured below (fig. 393). The Conifers of the Trias, lastly, are abundant, the most characteristic genus being *Voltzia*. This genus is related to the existing Cypresses, and many species of it are found in the Triassic Rocks.

Fig. 393.—*Neuropteris elegans*. Trias.

JURASSIC PLANTS.—Taken as a whole, the Jurassic period is characterised by the prevalence of Ferns, Cycads, and Conifers; no Palms or Angiospermous Exogens having been as yet shown to occur.

The Cycads are extremely abundant, and belong chiefly to the genera *Pterophyllum*, *Otozamites*, *Zamites*, *Bucklandia*, *Crossozamia*, *Williamsonia*, *Mantellia*, &c. The "dirt-bed," as it

is called, of the Purbeck beds, consists of an ancient soil, in which stand erect the trunks of Conifers and the stems of Cycads of the genus *Mantellia* (fig. 394). The fronds of

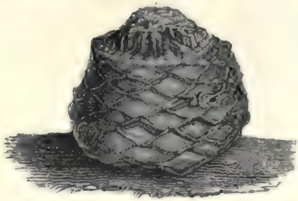


Fig. 394.—*Mantellia (Cycadeoidea) megalophylla*, a Cycad from the Purbeck "dirt-bed." Upper Oolites.

Fig. 395.—*Coniopteris Murravana*. Great Oolite.

Cycads occur also in great abundance in various Jurassic strata, especially in the lower portion of the series; and the

cones likewise have been in some instances preserved. The Conifers are represented by various genera more or less nearly allied to the present *Araucariæ*, and cones have been in a few instances detected.

Ferns occur very abundantly in the Jurassic series, the commonest genera being *Coniopteris* (fig. 395), *Odontopteris* (fig. 396), *Sphenopteris*, *Cyclopteris*, *Phlebopteris*, *Pecopteris*, *Polypodites*, *Pachypteris*, and *Tæniopteris*.

Endogens are by no means unknown in the Jurassic series, though no representative of the group of the Palms has been as yet detected. Amongst the most important of the Oolitic Endogens may be mentioned the Aroideous fruit described by Mr Carruthers under the name of *Aroides Stutterdi*, and the fruits known as *Podocarya* and *Kaidacarpum*, both of which belong to the living order of the *Pandaneæ* (Screw-pines).

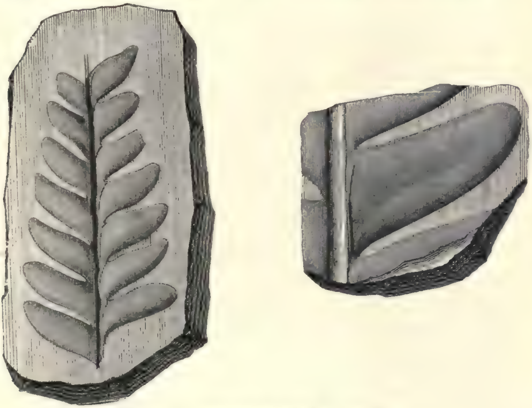


Fig. 396.—*Odontopteris cycadea*. Lower Lias.

CRETACEOUS PLANTS. — The Lower Cretaceous Plants greatly resemble those of the Jurassic period, consisting mainly of Ferns, Cycads, and Conifers. The Upper Cretaceous Rocks, however, both in Europe and in North America, have yielded an abundant flora which resembles the existing vegetation of the globe in consisting mainly of Angiospermous Exogens and of Monocotyledons. In Europe, the plant-remains in question have been found chiefly in certain sands in

the neighbourhood of Aix-la-Chapelle, and they consist of numerous Ferns, Conifers (such as *Cycadopteris*), Screw Pines (*Pandanus*), Oaks (*Quercus*), Walnut (*Juglans*), Fig (*Ficus*), and many *Proteaceæ*, some of which are referred to existing genera (*Dryandra*, *Banksia*, *Grevillea*, &c.)

In North America, the Cretaceous strata of New Jersey, Alabama, Nebraska, Kansas, &c., have yielded the remains of numerous plants, many of which belong to existing genera. Amongst these may be mentioned Tulip-trees (*Liriodendron*), Sassafras (fig. 397), Oaks (*Quercus*), Beeches (*Fagus*), Plane-

Fig. 397.—Cretaceous Angiosperms.—*a*, *Sassafras Cretaceum*; *b*, *Liriodendron Meekii*; *c*, *Leguminosites Marcouanus*; *d*, *Salix Meekii*. (After Dana.)

trees (*Platanus*), Alders (*Alnus*), Dog-wood (*Cornus*), Willows (*Salix*), Poplars (*Populus*), Cypresses (*Cupressus*), Bald Cypresses (*Taxodium*), Magnolias, &c. Besides these, however, there occur other forms which have now entirely disappeared from North America—as, for example, species of *Cinnamomum* and *Araucaria*.

Eocene Plants.—The Plants of the Eocene period ap-

proximate on the whole to the existing vegetation of the earth. They are, however, in the main most closely allied to forms which now are found in tropical or sub-tropical regions. In the London Clay occur numerous fruits of Palms (*Nipadites*, fig. 398), along with various other plants, most of which indicate a warm climate as prevailing in the South of England at the commencement of the Eocene period. In the Eocene strata of North America occur numerous plants, such as Palms, Conifers, Magnolia, Cinnamon, Fig, Dog-wood, Maple, Hickory, Poplar, Plane-trees, &c. Upon the whole, the Eocene flora of North America is nearly related to that of the Miocene strata of Europe, as well as to that now existing in the American area. We may conclude, therefore, that "the forests of the American Eocene resembled those of the European Miocene, and even of modern America" (Dana).

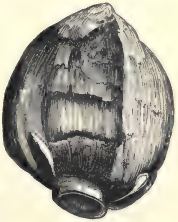


Fig. 398.—*Nipadites ellipticus.* London Clay of Sheppey.

MIOCENE PLANTS.—The deposits of the Miocene period have yielded an extraordinarily large number of plants, only a few of the more important of which can be indicated here. Our chief sources of information as to the vegetation of the Miocene period are derived from the Brown Coals of Germany and Austria, the Lower and Upper Molasse of Switzerland, and the Miocene strata of Greenland. The lignites of Austria have yielded very numer-

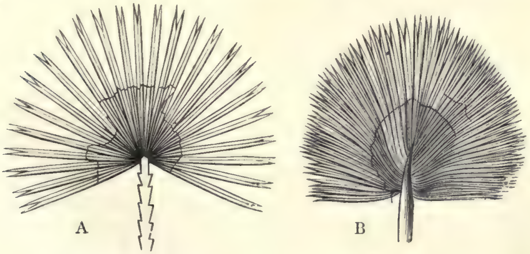


Fig. 399.—Miocene Palms. A, *Chamærops Helvetica;* B, *Sabal major.* Lower Miocene of Switzerland and France.

ous plant-remains, chiefly of a tropical character; one of the most noticeable forms being a Palm of the genus *Sabal*, (fig. 399, B), now found in America. The plants of the Lower Miocene of Switzerland are also mostly of a tropical character, but include several forms now found in North America, such as a Tulip-tree (*Liriodendron*) and a Cypress (*Taxodium*). Amongst the more remarkable forms from these beds may be mentioned Fan-Palms (*Chamærops*, fig. 399, A), numerous tropical ferns, and two species of Cinnamon. The plant-remains of the Upper Molasse of Switzerland indicate an extraordinarily rank and luxuriant vegetation, composed mainly of plants which now live in warm countries. Among the commoner plants of this formation may be enumerated many species of Maple (*Acer*), Plane-trees (*Platanus*, fig. 400), Cinnamon-trees, and other members of the *Lauraceæ*, many species of *Proteaceæ* (*Banksia*, *Grevillea*, &c.), several species of Sarsaparilla (*Smilax*), Palms, Cypresses, &c.

Fig. 400.—*Platanus aceroides.*—*a* Leaf; *b* The core of a bundle of pericarps; *c* A single fruit or pericarp, natural size. Upper Miocene.

Fig. 401.—*Cinnamomum polymorphum.* *a* Leaf; *b* Flower. Upper Miocene.

In Britain, the Lower Miocene strata of Bovey Tracy have yielded remains of Ferns, Vines, Fig, Cinnamon, *Proteaceæ*, &c., along with numerous Conifers. The most abundant of these last is a gigantic pine—the *Sequoia Couttsiæ*—which is very nearly allied to the huge *Sequoia* (*Wellingtonia*) *gigantea* of California. A nearly-allied form (*Sequoia Langsdorffii*) has been detected in the leaf-bed of Ardtun in the Hebrides.

In Greenland, as well as in other parts of the Arctic regions, Miocene strata have been discovered which have yielded a great number of plants, many of which are identical with species found in the European Miocene. Amongst these

plants are found many trees, such as Conifers, Beeches, Oaks, Maples, Plane-trees, Walnuts, Magnolias, &c., with numerous shrubs, ferns, and other smaller plants.

Taking the Miocene flora as a whole, Dr Heer concludes from his study of about 3000 plants contained in the European Miocene alone, that the Miocene plants indicate tropical or sub-tropical conditions, but that there is a striking intermixture of forms which are at present found in countries widely removed from one another. It is impossible to state with certainty how many of the Miocene plants belong to existing species, but it appears that the larger number are extinct. According to Heer, the American types of plants are most largely represented in the Miocene flora, next those of Europe and Asia, next those of Africa, and lastly those of Australia. Upon the whole, however, the Miocene flora of Europe is mostly nearly allied to the plants which we now find inhabiting the warmer parts of the United States; and this has led to the suggestion that in Miocene times the Atlantic Ocean was dry land, and that a migration of American plants to Europe was thus permitted. This view is borne out by the fact that the Miocene plants of Europe are most nearly allied to the living plants of the eastern or Atlantic seaboard of the United States, and also by the occurrence of a rich Miocene flora in Greenland. As regards Greenland, Dr Heer has determined that the Miocene plants indicate a temperate climate in that country, with a mean annual temperature at least 30° warmer than it is at present.

The present limit of trees is the isothermal which gives the mean temperature of 50° Fahr. in July, or about the parallel of 67° N. latitude. In Miocene times, however, the Limes, Cypresses, and Plane-trees reach the 79th degree of latitude, and the Pines and Poplars must have ranged even further north than this.

PLIOCENE PLANTS.—The vegetation of the Pliocene period is, upon the whole, so closely allied to that now existing as to call for no special mention. It is worthy of notice, however, that the Pliocene flora of Europe was strikingly similar to that now existing in North America. Thus, we find in the Pliocene of Europe genera such as the Locust-trees (*Robinia*), the Honey-locusts (*Gleditschia*), the Sumach (*Rhus*), the Bald Cypress (*Taxodium*), the Tulip-tree (*Liriodendron*), the Sweet-gum Tree (*Liquidambar*), the Sour-gum Tree (*Nyssa*), &c., which do not now occur in Europe, but are at present characteristic forms in the flora of temperate North America.

PART IV.

HISTORICAL PALÆONTOLOGY

HISTORICAL PALÆONTOLOGY.

CHAPTER XLVI.

LAURENTIAN AND CAMBRIAN PERIODS.

IN this portion of the work it will be endeavoured very briefly to give a view of the forms of life which characterised each of the great geological periods. The subject of the fossils which characterise each particular stratum or group of strata in the earth's crust is one far too vast to be grappled with here, and can only be properly considered in a special treatise. All that will be attempted here is to give a short synopsis of the deposits of each successive era, followed by a general account of the "life" of the period in which those deposits were laid down. Such an account may be advantageously prefaced by a tabular view of the more important fossiliferous deposits, commencing with the most ancient.

TABULAR VIEW OF FOSSILIFEROUS STRATA.

I. PALÆOZOIC OR PRIMARY EPOCH.

(*Terrains Paléozoïques.*)

1. LAURENTIAN.

a. *Lower Laurentian.* — *British* — Wanting. *Foreign* — Great series of metamorphic rocks in Canada, gneiss, mica-schist, quartzite, and limestones, with a total thickness of about 20,000 feet.

b. *Upper Laurentian.* — *British* — Fundamental Gneiss of the Hebrides (?); Hypersthene Rocks of the Isle of Skye (?). *Foreign* — Labrador Series of Canada, having a thickness of 10,000 feet, and resting unconformably upon the Lower Laurentian.

2. HURONIAN.

British — Wanting (?). *Foreign* — About 18,000 feet of metamorphic rocks resting unconformably upon the Laurentian series of Canada. Perhaps the equivalent of the Lower Cambrian of other regions.

3. Cambrian.

a. Lower Cambrian.—British—Longmynd group of Shropshire; Harlech Grits; Llanberis Slates; Green and purple slaty rocks of Wicklow, containing *Oldhamia*. *Foreign*—Fucoidal Sandstone of Sweden, with *Eophyton*; Etages A and B of Barrande in Bohemia; Huronian series of Canada (?).

b. Upper Cambrian.—British—Lingula Flags of Shropshire and Wales. Tremadoc Slates (?). Skiddaw Slates (?). *Foreign*—"Primordial zone" of Bohemia; Alum-schists of Sweden and Norway; Potsdam Sandstone and Calciferous Sand-rock of North America; Quebec group of Canada (?).

4. Silurian.

a. Lower Silurian.—

Britain.

1. Lower Llandeilo or Arenig Group.
2. Upper Llandeilo or Llandeilo Flags.
3. Caradoc, Bala, or Coniston Group.
4. Lower Llandovery Group.

North America.

1. Trenton Period (comprising the Chazy, Birds-eye, Black River, and Trenton Limestones).
2. Hudson Period (comprising the Utica Shales and Hudson River Group).

Bohemia.

Etage D of Barrande.

b. Upper Silurian.

Britain.

1. Upper Llandovery (comprising the Tarannon Shales and May Hill Sandstone).
2. Wenlock Group (comprising the Woolhope Limestone, Wenlock Shale, and Wenlock Limestone).
3. Ludlow Group (comprising the Lower and Upper Ludlow formations).

North America.

1. Niagara period (comprising the Oneida Conglomerate, Medina Sandstone, Clinton Group and Niagara Limestone).
2. Salina period (comprising the Guelph Limestone and Onondaga Salt Group).
3. Lower Helderberg period (comprising the Tentaculite and Waterlime Groups, the Lower Pentamerus Limestone, the Delthyris Shaly Limestone, and the Upper Pentamerus Limestone).

Bohemia.

Etage E.
—— F.
—— G.
—— H.

5. Devonian.

a. Lower Devonian.—British—Arbroath Paving Stones of Scotland; Linton Group of Devonshire. *Foreign* — Oriskany Sandstone (?) and Corniferous series of North America.

b. Middle Devonian.—British—Bituminous Schists of Caithness; Ilfracombe Group of Devonshire. *Foreign*—Eifel Limestone of Europe; Hamilton series of North America.

c. *UpperDevonian.—British*—Sandstones of Dura Den; Sandstones of Denholm Hill in Roxburghshire; Kiltorcan beds of Ireland; Pilton and Petherwyn Group of South of England. *Foreign*—Clymenien-Kalk, and Cypridinen-Schiefer of Germany; Portage, Chemung, and Catskill Groups of North America.

6. Carboniferous.

a. *Lower Carboniferous.—British*—Carboniferous Slates of Ireland; Mountain Limestone; Yoredale Series. *Foreign*—Sub-Carboniferous Group of North America.

b. *Upper Carboniferous—British*—Millstone Grit; Coal-Measures. *Foreign*—Equivalent beds in various parts of the world.

7. Permian.

a. *Lower Permian.—British*—Lower Red Sandstones of North of England. *Foreign*—Rothliegendes of Germany.

b. *Middle Permian.—British*—Marl Slate and Magnesian Limestone. *Foreign*—Mergel-schiefer, Kupfer-schiefer, and Zechstein of Germany.

c. *Upper Permian.—British*—Gypseous Marls and Red Sandstones of the North of England. *Foreign*—Bunter-schiefer of Germany.

II. Mesozoic or Secondary Epoch.

(*Terrains Secondaires.*)

8. Triassic Series.

a. *Lower Trias.—British*—New Red Sandstone of Lancashire and Cheshire. *Foreign*—Bunter Sandstein of Germany.

b. *Middle Trias.—British*—Wanting. *Foreign*—Muschelkalk of Germany.

c. *Upper Trias.—British*—Red marls, salt, &c. (Keuper), of Cheshire; Penarth, Rhætic, or *Avicula contorta* beds of Somersetshire, Glamorganshire, &c. *Foreign*—Keuper beds of Germany; Kössen (St Cassian) and Hallstadt beds of the Austrian Alps.

9. Jurassic Series.

a. *Lower Oolites.—British*—Lias, Inferior Oolite, Fuller's Earth, Great Oolite, Stonesfield Slate, Cornbrash, and Forest Marble. *Foreign*—The Sinemurien, Liasien, Toarcien, Bajocien, and Bathonien of D'Orbigny.

b. *Middle Oolites.—British*—Kelloway Rock, Oxford Clay, Coral Rag. *Foreign*—Nerinean Limestone of the Jura, Diceras Limestone of the Alps.

c. *Upper Oolites—British*—Kimmeridge Clay, Portland Stone, Purbeck beds. *Foreign*—Lithographic Slate of Solenhofen.

10. Cretaceous Series.

a. *Lower Cretaceous.—British*—Hastings Sands, Weald Clay, Lower Greensand, Kentish Rag. *Foreign*—Neocomian of Neufchatel, Wealden of Hanover.

b. *Upper Cretaceous.—British*—Gault, Blackdown beds, Upper Greensand, Chalk Marl, White Chalk. *Foreign*—Quader Sandstein and Pläner Kalk of Germany, Hippurite Limestone of the South of Europe, Maestricht Chalk, Faxoe Limestone, Sands and Marls of New Jersey in North America.

III. Kainozoic or Tertiary Epoch.

(*Terrains Tertiaires.*)

11. Eocene Series.

a. Lower Eocene.—British—Thanet Sands, Plastic and Mottled Clays of Woolwich, London Clay. *Foreign*—Sables de Bracheux and Argile plastique of France. Claiborne beds of Alabama, United States.

b. Middle Eocene.—British—Bagshot, Bracklesham and Barton beds, Headon Series, St Helens or Osborne Series. *Foreign*—Calcaire Grossier of France; Nummulitic Limestone of the Alps; Jackson beds of the United States.

c. Upper Eocene.—British—Bembridge beds, Hempstead beds (Lower Miocene?). *Foreign*—Gypseous Series of Montmartre in France, Vicksburg and White River beds in the United States.

12. Miocene Series.

a. Lower Miocene.—British—Bovey Tracy lignites and clays, Leaf-beds of Mull in the Hebrides. *Foreign*—Brown Coals of Germany and Croatia, Lower Molasse of Switzerland.

b. Upper Miocene.—British—Ferruginous Sands of North Downs (?). *Foreign*—Faluns of Touraine, Epplesheim Sands, Upper Molasse of Switzerland, Oeningen beds of Switzerland, Siwalik beds of India.

13. Pliocene Series.

a. Older Pliocene.—British—White Crag and Red Crag of Suffolk. *Foreign*—Upper and Middle Crags of Antwerp, Sub-Apennine beds.

b. Newer Pliocene.—British—Norwich Crag. *Foreign*—Lacustrine Strata of the Val d'Arno, near Florence.

14. Post-Tertiary Series.

a. Post-Pliocene.—Cave-deposits, High-level and low-level gravels, Glacial deposits, Forest-bed of Cromer, &c.

b. Recent.—Peat-mosses, recent river-gravels, lacustrine mud,&c.

Laurentian Period.

Rocks of the Period.—The Laurentian Rocks have their typical development in North America, especially in Canada. In northern New York strata of this age rise into the lofty and rugged elevations of the Adirondacks, and similar rocks occur in another area to the south of Lake Superior. The Laurentian series is of vast thickness, and is divided into a lower and upper division. The *Lower Laurentian* group attains the enormous thickness of about 20,000 feet, and is composed entirely of metamorphic rocks, consisting mainly of gneiss interstratified with mica-schist, with great beds of quartz, and massive beds of crystalline limestone, of which one varies from 700 to 1500 feet in thickness. Conglomerates also occur, and there are vast deposits of magnetic and specular iron-ore. Graphite or black-lead occurs disseminated in strings, veins, and beds, through hundreds of feet of Lower Laurentian strata, and its amount is calculated by Dr Dawson to be equal

in quantity to the coal-seams of an equal area of the Carboniferous rocks.

Not only is the Lower Laurentian series of vast thickness and greatly metamorphosed, but it must have been elevated above the sea, and subjected to vast denudation, prior to the deposition of the upper group. This is shown by the fact that the Upper Laurentian lies unconformably upon the truncated edges of the Lower Laurentian. The *Upper Laurentian* group is about 10,000 feet thick, and consists wholly of stratified crystalline rocks. These consist mainly of gneissic and felspathic rocks, often characterised by the occurrence of lime-felspar or Labradorite. The series is extensively developed in Labrador, and is sometimes spoken of as the "Labrador series."

In Britain it has been conjectured, with great probability, that the "fundamental gneiss" of the Hebrides and the "hypersthene rocks" of the Isle of Skye belong to the Laurentian series.

LIFE OF THE LAURENTIAN PERIOD.—The Laurentian rocks are often spoken of as the *Azoic series* (Gr. *a*, without; *zoe*, life); but the name appears to be inappropriate, because there is good evidence to show that living beings were in existence in the Laurentian period. In the first place, it is certain that the Laurentian rocks, though now highly metamorphic, were originally deposited as ordinary sedimentary beds of sandstone, conglomerate, shale, and limestone. There is, therefore, no reason whatever for supposing that the seas of the Laurentian period differed in any respect from modern seas, so far at any rate as to render the existence of living beings impossible; while we know that one of the results of metamorphic action is the obliteration of the fossils in the rock affected. Secondly, by the researches of Sir William Logan there was discovered in one of the limestones of the Lower Laurentian group, the body which has been described under the name of *Eozoön Canadense*, and which is believed to be a gigantic *Foraminifer*. The organic nature of this body was first detected by Dr Dawson of Montreal, and his opinion as to its nature has since been confirmed by the highest authorities. Thirdly, there is good reason to believe that the graphite of the Laurentian rocks is nothing more than metamorphic *coal*, and that it is derived from vegetables which flourished during the Laurentian period.

HURONIAN PERIOD.

The rocks of the Huronian series rest unconformably upon the denuded edges of the Laurentian rocks on the borders of

Lakes Superior and Huron. They are about 18,000 feet in thickness, and consist of quartzites (altered sandstones), siliceous slates, conglomerates, and limestones. The conglomerates sometimes contain pebbles derived from the subjacent Laurentian rocks. No fossils have hitherto been found in any part of the Huronian series, and its exact age is therefore doubtful. Not improbably it may correspond with the Lower Cambrian rocks of other regions, but it may represent an independent formation to be intercalated in point of time between the Laurentian and Cambrian groups.

CAMBRIAN PERIOD.

ROCKS OF THE PERIOD.—The exact limits of the *Cambrian Rocks* are as yet not well defined, different authorities taking different views as to the strata which should be considered under this head. The name "Cambrian" is derived from the fact that these strata are the lowest rocks visible in North Wales and its borders (Cambria). The Cambrian rocks are generally divided into a Lower and Upper division, and they are well developed in various parts of Europe and America. The following gives a general idea of the nature, distribution, and mineral characters of the Cambrian rocks :—

I. *Cambrian Rocks of Britain.*—The *Lower Cambrian* rocks of Britain are best seen in the Longmynd Hills in Shropshire, and consist of about 25,000 feet of variously-coloured sandstones, grits, and shales, often ripple-marked, and exhibiting rain-prints, but with very few fossils. These are succeeded by a great series of micaceous flagstones, slates, and shales, which vary in thickness from 6000 to 2000 feet, and are, in part at any rate, of *Upper Cambrian* age. They are known as the *Lingula Flags*, from the occurrence in them of a Brachiopod belonging to the genus *Lingula*. In North Wales the Lower Cambrian strata are often highly metamorphosed, and the celebrated Welsh roofing-slates are also derived from this division. Cambrian rocks occur in other parts of Britain, and the following table exhibits their leading members :—

1. *Lower Cambrian :*
    - *a.* Longmynd beds (25,000 feet).
    - *b.* Llanberis slates (3000 feet).
    - *c.* Harlech grits (6000 feet).
    - *d.* *Oldhamia* slates of Ireland.
2. *Upper Cambrian :*
    - *e.* Lingula Flags of Wales (about 6000 feet).
    - *f.* Tremadoc Slates of North Wales (2000 feet).
    - *g.* Skiddaw Slates of the north of England (7000 feet).

The last-mentioned group of rocks, namely, the Skiddaw Slates of the north of England, is in a doubtful position. They consist of about 7000 feet of dark-coloured shales and slates, and they are most clearly the equivalent of the Quebec group of Canada, containing many of the same fossils. Upon the whole, it seems safer in the meanwhile to regard them as Upper Cambrian.

II. *Cambrian Rocks of Bohemia and Sweden.*—In Bohemia, M. Barrande has succeeded in demonstrating as underlying the Lower Silurian rocks of that country a zone of rocks, which correspond to the Lingula Flags of Britain, and are therefore of Upper Cambrian age. This zone contains many remarkable and characteristic fossils, and is often spoken of as the "Primordial Zone." In Sweden and Norway the Lower Cambrian rocks are represented by a sandstone containing impressions supposed to be referable to sea-weeds or "fucoids." This "Fucoidal sandstone" is succeeded by beds of so-called "alum-schist," which are of Upper Cambrian age, and correspond with the Lingula Flags of Britain.

III. *Cambrian Rocks of North America.* — The Cambrian rocks are represented in North America by the Potsdam sandstone and the Calciferous series. The *Potsdam Sandstone* is mostly a laminated sandstone, or grit in the State of New York, but limestones are present in addition in the Mississippi basin, and it consists of a great thickness (2000 to 7000 feet) of slates, sandstones, and limestones, along the Appalachian chain. It contains a good many fossils, among which are Trilobites resembling those of the "Primordial Zone" in Bohemia.

The *Calciferous* series consists of a hard calcareous sandstone, or "sand-rock" in the State of New York; but it consists of sandstone with well-developed magnesian limestone in the basin of the Mississippi; and along the Appalachian chain it consists of sandstones and limestones, subordinated to great masses of shale. In their last-mentioned development the Calciferous rocks have been termed the "Quebec group," and, as before said, they are undoubtedly the equivalent of the Skiddaw Slates of Britain. They attain a thickness of from 5000 to 7000 feet; but it is not clear whether they are truly referable to the Upper Cambrian or to the base of the Silurian system. Most probably they are transition beds between the two formations.

Life of the Cambrian Period.—In the Lower Cambrian Rocks fossils have hitherto proved extremely scarce. The commonest organic remains are the burrows and tracks of

Annelides (*Arenicolites*, *Histioderma*, &c.) Besides these, the Longmynd beds of Shropshire have yielded a supposed Trilobite (*Palæopyge*). The green and purple slaty rocks of Wicklow have yielded two species of the singular fossil *Oldhamia* (fig. 27), which may be a Hydroid Zoophyte, but which is more probably a calcareous sea-weed. Lastly, the "Fucoidal Sandstone" of Sweden, besides the obscure remains which are known as "fucoids," has yielded the remarkable fossil known as *Eophyton* (fig. 378), which is most probably a plant, along with a small *Lingula*.

In the Upper Cambrian Rocks, fossils become tolerably abundant, and belong to varied types. The most characteristic forms are Trilobites, the characters of which are so peculiar as to have gained them the name of "primordial," applied also to the strata in which they are found. The chief genera are *Paradoxides* (fig. 114), *Conocephalus*, *Sao*, *Conocoryphe*, *Ellipsocephalus*, *Microdiscus*, *Agnostus*, &c. The "Primordial Zone" of Bohemia has also yielded a few Pteropods, Brachiopods, and Echinoderms. The Potsdam Sandstone of North America contains various primordial Trilobites (especially those of the genus *Dikelocephalus*), Brachiopods of the genera *Obolus*, *Obolella*, and *Lingula*, Gasteropods of the genera *Pleurotomaria* and *Ophileta*, Annelide-burrows (*Scolithus*), and numerous so-called "fucoids." Lastly, in the Potsdam Sandstone have been detected the earliest footprints, if they may be so termed, which have been as yet discovered. These have been described under the names of *Protichnites* and *Climactichnites*, and they have probably been produced by large Crustaceans.

The Lingula Flags of Britain owe their name to the occurrence in them of a large satchel-shaped *Lingula* (*L. Davisii*). Trilobites of the genera *Olenus*, *Agnostus*, *Paradoxides*, &c., occur, and remains of Phyllopodous Crustaceans (*Hymenocaris*) are by no means rare.

The Skiddaw and Quebec groups, as already mentioned, are in a doubtful position, and are often regarded as being referable to the Lower Silurian. They are chiefly noticeable for the great abundance of Graptolites which they have been shown to contain. Many of these belong to genera which pass up into the Silurian rocks (*Didymograpsus*, *Diplograpsus*, and *Climacograpsus*); but others belong to types which are exclusively confined to this horizon, and which are remarkably complex as compared with later forms. Amongst these may be mentioned the genera *Tetragrapsus* (fig. 32), *Dichograpsus* (fig. 33), *Loganograpsus*, and *Phyllograpsus*.

CHAPTER XLVIII.

SILURIAN PERIOD.

Rocks of the Period.

Following the Cambrian comes the great Silurian series of rocks, first clearly established and definitely worked out by Sir Roderick Murchison, the founder of the Silurian system. The exact limit between the Cambrian and Silurian formations is one which is not clearly defined, since there does not appear to be any general physical break between the two groups. The line of demarcation between them is, in the present state of our knowledge, an arbitrary line, and is derived chiefly from the characters of the *Trilobites.* There are rocks, however, such as the Tremadoc Slates, the Skiddaw Slates, and the Calciferous and Quebec groups, in which there is an intermixture of Cambrian with true Lower Silurian types. These rocks, therefore, might be regarded as Upper Cambrian or as Lower Silurian, or as passage-beds between the two. It is to be remembered, also, that the Tremadoc Slates and Lingula Flags are regarded by Sir Roderick Murchison as being the basement-beds of the Lower Silurian.

The name "Silurian" was proposed by Sir R. Murchison for a great series of strata lying below the Old Red Sandstone, and occupying those parts of Wales and England which were at one time occupied by the "Silures," a tribe of ancient Britons. The Silurian rocks are largely developed in Wales, the north of England, Scotland, and Ireland, in various parts of Europe, especially Bohemia, Saxony, Russia, and Sweden, and in the North American Continent. The entire series is divisible into the two sections of the Lower and Upper Silurian rocks, each in turn split up into smaller subdivisions, the names of which have usually been taken from localities where they are unusually well developed, or where they were first studied.

In Britain the Silurian Rocks are divided into the following groups from below upwards:—

a. Lower Llandeilo group, *b.* Upper Llandeilo group, *c.* Bala, Caradoc, or Coniston group, *d.* Lower Llandovery group,	Lower Silurian.
e. Upper Llandovery group, *f.* Wenlock group, *g.* Ludlow group,	Upper Silurian.

a. The *Lower Llandeilo* or *Arenig* group derives its name from the town of Llandeilo, in Wales, where it consists of dark-coloured micaceous flags, with earthy shales and gritty sandstones.

b. The *Upper Llandeilo* group consists of a great series of micaceous flags and dark-coloured shales, often with interstratified igneous matter. In Scotland the group consists of a great assemblage of shales and grits, the former mostly very dark in colour, often anthracitic, and charged with the remains of *Graptolites.*

c. The *Bala*, *Caradoc*, or *Coniston* group consists in Wales of slates, grits, and sandstones, with two interstratified limestones, the whole attaining a thickness of about 5500 feet. In the north of England this group consists of black flaggy beds, a well-marked limestone with intercalated shales, and black mudstones replete with Graptolites.

d. The *Lower Llandovery* group consists of slates and sandstones, with great beds of conglomerate.

e. The *Upper Llandovery* group forms in Britain the base of the Upper Silurians, and rests unconformably upon the Lower Llandovery. It consists of limestones, shales, conglomerates, sandstones, and slates, attaining a total thickness of nearly 2000 feet.

f. The *Wenlock* group consists of a great mass of shale and flagstone (Wenlock Shale), underlaid and surmounted by limestones, the whole attaining a thickness of 3000 feet.

g. The *Ludlow* group consists of shales, limestones, and sandstones in Wales, and of grits and shales in the north of England, having a total thickness of from 2000 to 4000 or 5000 feet.

In North America the Silurian series is magnificently developed, and is capable, like that of other parts of the world, of being separated into a Lower and Upper division. The annexed table shows the subdivisions of the Silurian series as developed in the State of New York, and their supposed British equivalents—the table being in ascending order :—

Silurian Strata of New York.	*British equivalents.*
1. Trenton period (comprising the Chazy, Bird's eye, Black River, and Trenton limestones. 2. Hudson period (comprising the Utica slates and Hudson River shales).	The Lower Silurian series (comprising the Llandeilo, Bala, and Lower Llandovery groups).
3. Niagara period (comprising the Oneida conglomerate, Medina sandstone, Clinton group, and Niagara limestone).	The lower portion of the Upper Silurian series (comprising the Upper Llandovery and Wenlock).

4. Salina period (comprising the Guelph limestone and Onondaga salt group).	No British equivalent.
5. The Lower Helderberg period (comprising the Tentaculite and Water-lime groups, the Lower Pentamerus limestone, the Delthyris shaly limestone, and the Upper Pentamerus limestone).	The higher portion of the Upper Silurian series (comprising the Ludlow group).

In Bohemia, as shown by M. Barrande, the Silurian series likewise admits of a subdivision into an Inferior and a Superior division. The former comprises the single "étage D," and is characterised by a fauna to which M. Barrande has applied the term of "second fauna," the so-called "primordial zone" having yielded the "first fauna" of the same palæontologist. The Upper Silurian series comprises the étages E, F, G, and H, and is characterised by the possession of the "third fauna."

LIFE OF THE SILURIAN PERIOD.—In the lower portion of the Cambrian series, as we have seen, organic remains are exceedingly scanty; but in the upper portion of the same, fossils are tolerably abundant, and belong in part to types which pass upwards into the overlying Silurian series. The fossils of the Silurian series are almost exclusively marine, the only exceptions being some remains of land-plants, such as stems of *Lepidodendron* (*Sagenaria*) and the sporangia of Lycopodiaceous plants (*Pachytheca*), the latter having been discovered in the very highest beds of the system. The only other vegetable remains which have been detected in undoubted Silurian deposits belong to what are loosely termed "fucoids" (*Licrophycus*, *Arthrophycus*, *Palæophycus*, *Buthotrephis*, &c.), and these are tolerably abundant in various parts of the series.

The sub-kingdom of the *Protozoa* is represented by Foraminiferous shells and by Sponges. The latter are tolerably abundant in both the Lower and Upper Silurian and belong to various genera (*Palæospongia*, *Acanthospongia*, *Astylospongia*, *Amphispongia*, &c.) Here, also, we meet with the singular genera *Receptaculites* and *Ischadites*, which have been variously regarded as gigantic Foraminifers, as Sponges, or as intermediate forms between the *Foraminifera* and the *Spongida*.

The sub-kingdom of the *Cœlenterata* is represented in Silurian times by the *Graptolites* and by numerous Corals. The typical Graptolites commence their existence in the Skiddaw and Quebec Groups (Upper Cambrian ?), and are highly characteristic of the Silurian Rocks. If we except the genus *Dictyonema*, which is probably referable to the Sertularians, no species of Graptolite is known to have survived the close of the Silurian period. Neglecting their earlier appearance, the

genera *Didymograpsus* and *Dicranograpsus* are exclusively, and the genera *Diplograpsus*, *Climacograpsus*, and *Rastrites* are pre-eminently, characteristic of the *Lower* Silurian period. The genera *Graptolites* and *Retiolites* are those which especially characterise the *Upper* Silurian deposits, though both commence in the inferior division of the series. Corals are exceedingly abundant in many parts of the Silurian series, certain formations, such as the Wenlock Limestone of England and the Niagara Limestone of North America, being in places so largely composed of these fossils that they have been regarded as ancient coral-reefs. Almost all the Silurian corals belong to the groups of the *Rugosa* and *Tabulata*.

The *Echinodermata* are largely represented in Silurian dedeposits, more especially by Crinoids and Cystideans. The former are extremely abundant, and belong in many instances to peculiar types. The Cystideans are pre-eminently Lower Silurian, though they occur also in the upper division of the series. They are especially characteristic of the Bala or Caradoc period. The true Star-fishes (*Asteroidea*) are represented even in the Lower Silurian rocks; whilst the Brittle-stars (*Ophiuroidea*) are represented by the genus *Protaster*. The Sea-urchins (*Echinoidea*) are not represented at all except in the Upper Silurian, and there only by the aberrant genus *Palæchinus*.

The *Annelida* are represented in the Silurian rocks by the tracks and burrows of Sea-worms (*Helminthites* and *Scolites*), and by the tubes of *Tubicola* (*Serpulites*, *Ortonia*, *Conchicolites*, *Cornulites*, *Spirorbis*, &c.) The little spiral tubes of *Spirorbis* are commonly found in the Upper Silurian rocks attached to the shells of *Orthocerata* and the like.

The *Arthropoda* appear to have been represented wholly by Crustaceans, no Arachnids, Myriapods, or Insects being yet known with certainty to occur. The most important Silurian Crustaceans belong to the *Trilobita*, *Phyllopoda*, *Eurypterida*, and *Ostracoda*. The Trilobites are extraordinarily abundant, and every subdivision of the Silurian series has its characteristic species. The "primordial Trilobites" are only represented by such forms as *Agnostus* and *Olenus*. The Lower Silurians have many types, amongst which *Asaphus*, *Ogygia*, *Trinucleus* *Calymene*, *Cheirurus*, *Illænus*, and *Phacops* may be mentioned as the most important, though most of these range into the Upper Silurians as well. The Silurian Phyllopods are tolerably plentiful in both divisions of the series and belong chiefly to the genera *Ceratiocaris*, *Peltocaris*, and *Discinocaris*. The Eurypterids are represented in the Lower Silurians, but they

are pre-eminently characteristic of the higher beds of the Upper Silurian. Lastly, the *Ostracoda* are often extremely abundant, and belong chiefly to the genera *Leperditia*, *Primitia*, *Beyrichia*, and *Entomis*.

The sub-kingdom *Mollusca* is very largely represented in Silurian deposits, and the Brachiopods and Tetrabranchiate Cephalopods in particular enjoyed a vast extension and a development which has never since been attained. The Brachiopods are so abundant in all parts of the series that the Silurian period has been spoken of as the "Age of Brachiopods." The chief families are the *Strophomenidæ*, *Rhynchonellidæ*, *Spiriferidæ*, and *Lingulidæ*. The genus *Pentamerus* is especially characteristic of the Llandovery Rocks, or of what has been termed the "Middle Silurian" by Sir Charles Lyell. The Caradoc period is noticeable for the great number of *Orthides*, mostly belonging to simple plaited forms. The exclusively Silurian genera, however, are very few, but *Obolus*, *Siphonotreta*, and *Trematis* are not known to have survived into the Devonian period. Bivalves, such as *Modiolopsis*, *Ctenodonta*, *Lyrodesma*, *Ambonychia*, *Pterinea*, *Cardiola*, &c., are far from uncommon; whilst the Gasteropods are largely represented by such forms as *Pleurotomaria*, *Metoptoma*, *Holopea*, *Cyclonema*, and *Murchisonia*. The Heteropods are represented by *Maclurea*, *Bellerophon*, *Cyrtolites*, and *Ecculiomphalus;* and the Pteropods abounded under the generic forms of *Theca* (*Hyolithes*), *Conularia*, *Tentaculites*, and *Pterotheca*. The Tetrabranchiate Cephalopods are extraordinarily abundant; but they belong almost exclusively to the sections of the *Nautilidæ* and *Orthoceratidæ;* the *Ammonitidæ* being represented only by the genus *Goniatites*, which has not as yet been recognised in the Lower Silurian deposits. The family of the *Orthoceratidæ* attains here its maximum of development, over one thousand species having been described by M. Barrande from the Silurian basin of Bohemia alone. Their highest development, however, is in the upper and not in the lower division of the series.

The sub-kingdom *Vertebrata* is not known to be represented in the Lower Silurian period at all; but remains of various fishes have been detected in the Upper Silurian series. In Britain, the earliest fish-remains have been discovered in the Lower Ludlow Shale, and consist of the cephalic bucklers of Pteraspidean fishes. In the well-known stratum at the summit of the Ludlow Rocks, familiar under the name of the "bone-bed," have been discovered the defensive spines on which the genus *Onchus* has been founded, and the shagreen-scales

which constitute the genera *Thelodus* and *Sphagodus*. These spines are believed to indicate the existence in the Upper Silurian seas of Cestraciont fishes allied to the living Port-Jackson Shark, whilst the latter may have belonged to some form like the existing Dog-fishes. It must be admitted, however, that the true nature of these fossils is still open to question. From the Upper Silurian series of Bohemia M. Barrande describes no less than five fishes—viz., *Coccosteus primus*, *C. Agassizi*, *Asterolepis Bohemicus*, *Gompholepis Panderi*, and *Ctenacanthus Bohemicus*, of which the first four belong to the Ganoids, whilst the last is supposed to be a Cestraciont or a Selachian.

CHAPTER XLIX.

DEVONIAN PERIOD.

ROCKS OF THE PERIOD.

THE Silurian Rocks are succeeded upward by a great system of rocks, mainly of the nature of sandstones and conglomerates, to which the name of *Old Red Sandstone* has been applied. The name *Devonian* formation is also employed to designate these same strata, rocks supposed to belong to this period being largely developed in Devonshire, in England. It is probable, however, that the Devonian rocks represent a portion only of the Old Red Sandstone, and that they cannot be regarded as the full equivalent of the Old Red Sandstone of other regions. The term "Devonian" may, however, when thus understood, be usefully employed as a general term for all the strata which intervene between the Silurian System and the succeeding formation of the Carboniferous rocks.

The uncertainty as to the exact position of the Devonian Rocks of Devonshire in the series of the Old Red Sandstone, or the uncertainty as to whether they represent the Old Red Sandstone in whole or in part, arises from this—that though both formations are fossiliferous, the peculiar fossils of each are never found associated together. The peculiar fossils of the Old Red Sandstone proper are not found in the rocks of Devonshire; and the fossils of the latter, though found in equivalent strata on the Continent of Europe, do not occur in the beds to which the name of Old Red Sandstone was originally applied. This, however, may be largely due to the fact

that, while the Devonian strata are undoubtedly marine in their origin, there seems reason to conclude that the Old Red Sandstone proper was, in part at any rate, a fresh-water deposit. The two groups, therefore, might be truly contemporaneous, and yet might not contain the same fossils.

The Old Red Sandstone is pre-eminently a British formation, and is divisible into three groups—the Lower, Middle, and Upper Old Red.

The *Lower Old Red* reposes with perfect conformity upon the highest beds of the Upper Silurians, the two formations appearing to pass into one another by an intermediate series of "passage-beds," which contain large Crustaceans of the family of the *Eurypterids*. The Lower Old Red consists mainly of massive conglomerates, with sandstones, shales, and concretionary limestones. Its organic remains consist chiefly of plants, Crustaceans, and fishes.

The *Middle Old Red* of Scotland consists of dark-grey flagstones, bituminous, flaggy shales, and conglomerates, sometimes accompanied by shales having irregular calcareous nodules embedded in them. The fossil remains are chiefly fishes, with one Crustacean, and a few plants.

The *Upper Old Red* of Scotland consists of pebbly conglomerates, sandstones, and shales, and contains many fishes, a good many fragments supposed to belong to sea-weeds, and some undoubted land-plants.

In North and South Devon there occurs, underlying the Carboniferous Rocks, a great series of strata which has been regarded as the equivalent of the Old Red Sandstone. Though certainly referable, in great part at any rate, to the period of the Old Red Sandstone, it does not appear that the Devonian Rocks can be regarded as the *equivalent* of the Old Red Sandstone of Scotland. The Devonian Rocks, however, are largely represented on the continent of Europe, and they are richly fossiliferous; though they do not contain any of the characteristic *Crustaceans*, and only one or two generic representatives of the characteristic *fishes* of the Scotch Old Red.

The Devonian Rocks of Devonshire consist essentially of greenish slates, alternating with sandstones, conglomerates, and well-developed bands of blue crystalline limestone and calcareous slates.

In no country in the world probably is there a finer and more complete exposition of the strata intervening between the Silurian and Carboniferous formations than in the United States. The following are the main subdivisions of the Devo-

nian Rocks of the State of New York, in which, probably, the series is most typically displayed:—

1. Oriskany period (Oriskany Sandstone),* 2. Corniferous period (comprising the Cauda-Galli grit, Schoharie grit, and Upper Helderberg group),	Lower Devonian.
3. Hamilton period (comprising the Marcellus, Hamilton, and Genesee groups), 4. Chemung period (comprising the Portage and Chemung groups), 5. Catskill period (Catskill Sandstone),	Upper Devonian.

LIFE OF THE DEVONIAN PERIOD.—Taken as a whole, the life of the Devonian period may be regarded as transitional between that of the underlying Silurian and overlying Carboniferous period. As far, however, as our present knowledge allows of our forming a definite opinion, the Devonian fauna and flora approximate more nearly to those of the succeeding Carboniferous than to those of the antecedent Silurian period. This is especially shown in the Devonian plants, which, as has been already pointed out, in almost all cases agree generically with those of the Carboniferous; whilst in some cases they are even specifically identical. Thus, the Devonian land supported an abundant vegetation, in which Lepidodendroids, Sigillarioids, Calamites, Ferns, and Conifers, mostly of Carboniferous types, play a prominent part. There are, however, some forms, which, like *Psilophyton*, are as yet not known to have occurred in the Carboniferous deposits.

The *Protozoa* are represented in the Devonian rocks by *Foraminifera* and Sponges. Of the latter, *Sparsispongia* is the most characteristic genus. (*Steganodictyum* is the buckler of a Pteraspidean fish.)

The *Cœlenterata* are represented by the Hydrozoal genus *Dictyonema*, which has often been referred to the Graptolites, and by very numerous and varied forms of corals. No true Graptolites have been as yet detected, unless *Dictyonema* be one. The corals still belong mainly to the groups of the *Rugosa* and *Tabulata*. The section of the *Tubulosa* (*Auloporidæ*) is represented here for the first time. Here also occur the singular operculate Rugose corals upon which the genus *Calceola* is founded.

The *Echinodermata* are represented in the Devonian period by numerous Crinoids (*Cupressocrinus*, *Aplocrinus*, *Platycri-*

* The Oriskany Sandstone, though here placed in the Devonian, is probably really the summit of the Upper Silurian.

nus, &c.), along with *Pentremites;* whilst Cystideans are stated to make their last appearance here.

The *Articulates* are represented by numerous Crustaceans, and by a few insects—the latter being the first of their class. The Crustaceans are abundant, the chief forms being Trilobites (*Phacops*, *Bronteus*, *Homalonotus*, &c.), large Eurypterids (*Pterygotus*, *Stylonurus*, *Eurypterus*, &c.), and Ostracodes (*Entomis*, *Leperditia*, *Beyrichia*, &c.) The bivalved carapaces of the last mentioned of these groups are very abundant in certain Devonian beds, and the so-called "Cypridinen-schiefer" of the Devonian series of Germany derives its name from the occurrence in it of vast numbers of the little *Entomis* (*Cypridina*) *serrato-striata*. In certain Devonian beds, also, the remains of the Crustacean genus *Estheria* are very abundant. The Devonian Insects appear on the whole to have the closest affinity with certain of the existing *Neuroptera* or *Pseudo-neuroptera*.

The *Mollusca* are largely represented in Devonian time, and the Brachiopods are especially abundant. The most characteristic forms are those of the genera *Stringocephalus* (fig. 144) and *Uncites*, along with numerous broad-winged *Spirifers* (such as *S. mucronata*, fig. 148). Lamellibranchs (such as *Megalodon* and *Pterinea*), Gasteropods (*Macrocheilus*, *Trochus*, *Pleurotomaria*, &c.), and Pteropods (*Conularia*) are well represented in the Devonian Rocks. As in the case of the Silurian period, no certain traces of the existence of Dibranchiate Cephalopods have been as yet detected in the Devonian. The Tetrabranchiate Cephalopods, however, are known by true *Nautili* and *Orthocerata*, and by the genus *Clymenia*. The family of the *Ammonitidæ* is also represented by the genera *Goniatites* and *Bactrites*.

The sub-kingdom of the *Vertebrata* is still represented by fishes only; but these are so abundant that the Devonian period has been commonly called the "Age of Fishes." Most of the Devonian Fishes belong to the order of the Ganoids, and especially to the two groups of the *Crossopterygidæ* and *Ostracostei*. The genera *Cephalaspis*, *Pteraspis*, *Pterichthys*, and *Coccosteus*, do not survive this period, and there are many other peculiar Lepidoganoids as well. Besides Ganoids, numerous remains of *Elasmobranchii* have been detected, these being referable both to the *Cestraphori* and to the *Selachii*. It is probable, also, that some of the Devonian fishes are rightly referable to the order *Dipnoi*, finding their nearest living allies in the Mud-fishes of South America and Africa, and the Barramunda of Australia.

CHAPTER L.

CARBONIFEROUS PERIOD.

Rocks of the Period.

Overlying the great formation of the Old Red Sandstone, or Devonian Rocks, sometimes unconformably but more often in perfect conformity, we have the large and important series of the *Carboniferous Rocks*, so called because workable beds of coal are more commonly developed in this than in any other formation. It must not be forgotten, however, that coal is not exclusively a Carboniferous product, but that workable seams of coal occur in several formations younger than the Carboniferous. In all cases, too, the coal forms but a very small proportion of the actual thickness of the Carboniferous Rocks, occurring in comparatively thin beds intercalated in a great series of sandstones, shales, and limestones.

The Carboniferous Rocks are largely developed in Britain, on the continent of Europe, and in North America, and are known to occur in other parts of the world also. Their general composition, however, is, comparatively speaking, so uniform, that it will be sufficient to take a general view of the formation without considering each area separately. As a general rule, the Carboniferous Rocks may be divided into the following three groups, from below upward :—

1. The *Carboniferous Slates* and *Mountain Limestone*, mainly and most typically calcareous. Sometimes termed the Subcarboniferous group.

2. The *Millstone Grit*, essentially arenaceous and conglomeratic.

3. The *Coal-measures*, composed of alternating shales, sandstones, and other strata, with workable beds of coal.

I. The Carboniferous, Sub-carboniferous, or Mountain, Limestone constitutes ordinarily the base of the Carboniferous system. In Ireland, however, and elsewhere, the lowest beds of the Carboniferous series are slates and grits, which attain a maximum thickness of 5000 feet, and have been termed the *Carboniferous Slates*. Their fossils are partially referable to good Carboniferous types, and partly to Devonian forms, so that they may be regarded as passage-beds. The Carboniferous limestone proper in its most typical development, as in Wales and the west of England, consists of a great mass of nearly pure limestone, from 1000 to 2000 feet thick, with a

few beds of shale. In other places, however, it is more or less broken up into a series of different beds of limestone, alternating with sandstones, grits, and shales, and sometimes containing beds of coal. In North America it is never purely calcareous, but consists mainly, or entirely, of sandstones and shales, sometimes with thin beds of coal, or deposits of clay iron-ore. Westward, however, it becomes more highly calcareous.

II. THE MILLSTONE GRIT.—The highest beds of the Carboniferous limestone are succeeded, usually conformably but sometimes unconformably, by a series of sandy and gritty beds which have been termed the *Millstone Grit.* In its most typical form the Millstone Grit consists of a series of hard quartzose sandstones, the component grains of which are sometimes so large as to be more properly called small pebbles, when the rock becomes a fine conglomerate. In other cases regular conglomerates are present, and there are sometimes shales, limestones, and thin beds of coal. The thickness of the Millstone Grit varies from 1000 to 1700 feet as a rule; but sometimes its thickness is very greatly diminished. Fossils are scarce, and offer no peculiarity.

III. THE COAL-MEASURES. — The Coal-measures proper succeed the Millstone Grit conformably, and consist of a great series of shale, sandstone, grit, and coal, attaining a total thickness, when well developed, of from 7000 to 15,000 feet. Except in Scotland, where workable coal-seams occur below the horizon of the Millstone Grit, it is mostly from the true Coal-measures that coal is obtained; the largest and most productive coal-fields of the world occurring in Britain, North America, and Belgium. In their mineral nature, the Coal-measures, all over the world, exhibit a wonderful *general* uniformity of composition. They consist, namely, of dark, often nearly black, earthy and laminated shales, yellow, brown, and purple sandstones, sometimes spotted, but very rarely red in colour, along with occasional beds of limestone and clay iron-ore, and beds of coal of varying thickness. These alternating beds may follow one another in any order, and may be repeated over and over again, the total thickness sometimes reaching the enormous amount of 14,000 feet, or nearly three miles. In the South Wales coal-field the series consists as usual of sandstones, shales, and coals, alternating with one another, and indicating a slow, but probably intermittent, depression of the area which they now occupy. In this coal-field there are about 80 distinct beds of coal, each of which represents an ancient land-surface. Each of these beds re-

poses upon a sandy shale or clay, which is known as the "underclay" or "floor" of the coal, and through which spread numerous fossils referred to the genus *Stigmaria*, and now known to be the roots of plants (*Sigillaria*). Each seam is also surmounted by a bed of shale, forming the so-called "roof" of the coal, and in this are found numerous flattened and compressed branches and stems of plants.

LIFE OF THE PERIOD.—The vegetation of the Carboniferous period is exceedingly luxuriant; but its characters have been already so fully discussed as to render unnecessary anything further here than a mere allusion to its chief members. The chief feature in the Carboniferous flora is the great predominance of Cryptogams as compared with Phanerogams. The former are amply represented by numerous Ferns, Calamites, Lepidodendroids, and, perhaps, Sigillarioids. The latter, with few exceptions, are represented only by Gymnospermous Exogens.

The *Protozoa* are represented in the Carboniferous rocks by a few Sponges and by the shells of *Foraminifera*, of which the genus *Fusulina* (fig. 11) is the most characteristic. The tests of this form are sometimes so abundant as almost to make up the whole of certain limestones.

The *Cœlenterates* are represented almost exclusively by Corals, which abound especially in some of the limestones of the Lower Carboniferous series. Most of the Carboniferous Corals belong to the Tabulate division of the *Zoantharia Sclerodermata*, or to the *Rugosa*, and amongst the more important genera may be mentioned *Lithostrotion*, *Syringopora*, *Lonsdaleia*, *Cyathophyllum*, *Amplexus*, *Favosites*, and *Chætetes*.

Of the *Echinodermata* the most abundant are the Crinoids, which occur in vast profusion in most of the limestones of the Carboniferous series. The most important genera are *Actinocrinus*, *Platycrinus*, *Cyathocrinus*, *Poteriocrinus*, and *Rhodocrinus*. In some parts of the Carboniferous, Pentremites are also exceedingly abundant. Lastly, the Echinoids are represented by the two aberrant genera, *Archæocidaris* and *Palæchinus*.

Annelides are not abundant, with the single exception of the little *Spirorbis*, or *Microconchus*, *carbonarius*, which sometimes occurs in great plenty. The Crustaceans belong chiefly to the groups of the *Ostracoda* and *Phyllopoda*. The Trilobites make here their last appearance; the genera *Phillipsia*, *Griffithides*, and *Brachymetopus*, being the last of the race. The Eurypterids also appear to die out finally in the Carboniferous. On the other hand, the *Xiphosura* are now represented by the genera *Belinurus* and *Prestwichia* (fig. 119); and the Macrourous Decapods appear to commence their existence

at this point. Of the Phyllopods, the best-known genera are *Dithyrocaris* and *Leaia*. The little *Ostracoda* are often exceedingly abundant, some of them belonging to marine, and others to fresh-water or brackish-water forms. About thirteen genera have been already detected in rocks of Carboniferous age, the most important being *Leperditia*, *Bairdia*, *Cypridina*, *Cythere*, *Candona*, and *Beyrichia*, of which the last appears to die out here. Besides Crustaceans, the Arthropods are represented by *Arachnida*, *Myriapoda*, and *Insecta*.

The *Mollusca* are very largely represented in Carboniferous seas. *Polyzoa* are very abundant, the most characteristic forms belonging to the genera *Fenestella*, *Ptilopora*, *Retepora*, and *Archimedipora*. Brachiopods occur in profusion, and belong as a rule to very well marked types. The great family of the *Productidæ* attains here its maximum, most of the remaining forms belonging to the genera *Spirifera*, *Strophomena*, *Orthis*, *Lingula*, *Terebratula*, and *Discina*. Bivalves are very numerous, and the family of the *Aviculidæ* reaches here its maximum of development. Other well-known Carboniferous Bivalves belong to the genera *Edmondia*, *Posidonomya*, *Conocardium*, and *Cardiomorpha*. The Gasteropods are represented mainly by the characteristically Palæozoic genera *Macrocheilus* and *Loxonema*, the almost exclusively Palæozoic *Euomphalus*, and the persistent genus *Pleurotomaria*. Heteropods (*Bellerophon* and *Porcellia*) and Pteropods (*Conularia*) are also not unknown. No Dibranchiate Cephalopods are as yet known to occur, but the Tetrabranchiates are well represented—the *Nautilidæ* by forms of *Orthoceras* and *Cyrtoceras*, and the *Ammonitidæ* by *Goniatites*.

The Vertebrates are now represented by Amphibians, in addition to Fishes. The latter are still chiefly Ganoid, the commonest forms belonging to the genera *Palæoniscus*, *Rhizodus*, and *Holoptychius*. Besides these occur numerous teeth and fin-spines referred to *Elasmobranchii*, the most important genera founded on these remains being *Psammodus*, *Orodus*, *Cochliodus*, *Cladodus*, *Ctenacanthus*, *Pleuracanthus*, *Gyracanthus*, *Leptacanthus*, and *Orthacanthus*. The Amphibians appear to belong exclusively to the extinct order of the *Labyrinthodontia*, referred to many genera, of which the most important are *Archegosaurus*, *Anthracosaurus*, and *Baphetes*. Some of the remains, however, of the air-breathing Vertebrates of the Carboniferous period are perhaps higher in the scale than Labyrinthodonts; and they have been supposed to indicate the existence at this time of true Reptiles.

PERMIAN PERIOD.

ROCKS OF THE PERIOD.—The Carboniferous series is succeeded by a group of beds, which complete the Palæozoic formations, and which were termed *Permian Rocks* by Sir Roderick Murchison, from the province of Perm, in Russia, where they are extensively developed. Formerly these rocks were grouped with the succeeding formation of the Trias under the common name of "New Red Sandstone." This name was given them because they contain a good deal of red sandstone, and because they are superior to the Carboniferous rocks, while the Old Red Sandstone is inferior. Nowadays, however, the term "New Red Sandstone" is rarely employed, unless it be for red sandstones and associated rocks, which are seen to overlie the Coal-measures, but which contain no fossils by which their exact age may be made out. Under these circumstances it is sometimes convenient to employ the term "New Red Sandstone." The New Red, however, of the older geologists is now broken up into the two formations of the Permian and Triassic rocks, the former being the top of the Palæozoic series, and the latter constituting the base of the Mesozoic.

The Permian rocks, as a rule, repose unconformably upon the underlying Carboniferous rocks, but seem to pass upward conformably into the Trias, in most instances. The division, therefore, between the Permian and Triassic rocks, and, consequently, between the Palæozoic and Mesozoic series, is not founded upon any marked or universal physical break, but upon the difference in the life of the two periods.

The Permian rocks exhibit their most typical features in Russia and Germany, though they are very well developed in parts of Britain, and they occur in North America. When well developed, they exhibit three main divisions: a lower set of sandstones, a middle group, generally calcareous, and an upper series of sandstones, constituting respectively the Lower, Middle, and Upper Permians.

In Russia, Germany, and Britain, the Permian rocks consist of the following members:—

1. The *Lower Permians* consisting mainly of a great series of sandstones, of different colours, but usually red. The base of this series is often constituted by massive breccias with included fragments of the older rocks, upon which they may happen to repose; and similar breccias sometimes occur in the upper portion of the series as well. The thickness of this

group varies a good deal, but may amount to 3000 or 4000 feet.

2. The *Middle Permians*, consisting, in their typical development, of laminated marls, or "marl-slate," surmounted by beds of magnesian limestone (the "Zechstein" of the German geologists). Sometimes the limestones are degenerate or wholly deficient, and the series may consist of sandy shales and gypsiferous clays. The magnesian limestone, however, of the Middle Permians is, as a rule, so well marked a feature that it was long spoken of as *the* Magnesian Limestone.

3. The *Upper Permians*, consisting of a series of sandstones and shales, or of red or mottled marls, often gypsiferous, and sometimes including beds of limestone.

In North America, the Permian rocks appear to be confined to the region west of the Mississippi, being especially well developed in Kansas. Their exact limits have not as yet been made out, and their total thickness is not more than a few hundred feet. They consist of sandstones, conglomerates, limestones, marls, and beds of gypsum.

LIFE OF THE PERIOD.—The Permian Rocks have yielded a very considerable number of plants, most of which are specifically distinct from those of the Coal-measures. Though the species, however, are distinct, many of the Permian genera date back to the antecedent Carboniferous period. Thus, besides several genera of Carboniferous Ferns, the Permian Rocks contain the well-known genera *Lepidodendron* and *Calamites*. The Sigillarioids, however, seem to have finally disappeared. Conifers are by no means uncommon, and some of these (*Ullmania*) produce true cones. The genus *Walchia* comprises the most characteristic of the Permian Conifers.

The *Protozoa* are represented in the Permian deposits by a few Sponges and *Foraminifera*. The *Cœlenterates* are represented by Corals, but these are rarely abundant. The *Rugosa* are reduced here to the single genus *Polycœlia*. Crustaceans are also by no means largely represented. The *Trilobita* have disappeared, as have the Eurypterids. The King-crabs (*Limulus*) are, however, represented by one species. *Ostracoda* are tolerably abundant, and the genus *Prosoponiscus* has been regarded as referable to either the *Isopoda* or the *Amphipoda*. Lastly, the genus *Hemitrochiscus* has been founded for the reception of a Permian fossil which has been regarded as the remains of a true Crab. If this determination be correct, the tribe of Brachyurous Decapods has its commencement here.

Molluscs occur in greater abundance than any of the preceding. The genera *Fenestella* and *Acanthocladia* represent the

Polyzoa. The most important genera of Brachiopods are *Spirifera*, *Producta*, *Strophalosia*, *Camarophoria*, and *Lingula*. Bivalves are moderately numerous, the commonest forms belonging to the family *Trigoniadæ* and to the genus *Axinus* (*Schizodus*). Other forms belong to the genera *Mytilus*, *Bakewellia*, and *Avicula*. Gasteropods and Cephalopods are, upon the whole, very poorly represented in the Permian series.

The most important Permian fossils are referable to the *Vertebrata.* Fishes are comparatively very abundant, and belong almost entirely to the order of the Ganoids. The most characteristic genera are *Palæoniscus*, *Platysomus*, *Pygopterus*, *Gyropristis*, *Acrolepis*, and *Cœlacanthus.* The Amphibians are represented by various forms belonging to the *Labyrinthodontia.* True Reptiles are represented by the *Protorosaurus* of the "Kupfer-schiefer" of Germany, and somewhat doubtfully by the Chelonian footprints (*Chelichnus*) from the Permian Sandstones of Dumfriesshire.

CHAPTER LI.

TRIASSIC PERIOD.

Rocks of the Period.

We come now to the consideration of the great *Mesozoic*, or Secondary series of formations, consisting, in ascending order, of the Triassic, Jurassic, and Cretaceous systems. The Triassic group forms the base of the Mesozoic series, and corresponds with the higher portion of the New Red Sandstone of the older geologists. Like the Permian Rocks, and as implied by its name, the *Trias* admits of a subdivision into three groups—a Lower, Middle, and Upper Trias. Of these subdivisions the middle one is wanting in Britain; and all have received German names, being more largely and typically developed in Germany than in any other country. Thus, the Lower Trias is known as the *Bunter Sandstein;* the Middle Trias is called the *Muschelkalk*, and the Upper Trias is known as the *Keuper.*

I. The lowest division of the Trias is known as the *Bunter Sandstein*, from the generally variegated colours of the beds which compose it (German, *bunt*, variegated). The Bunter Sandstein of the continent of Europe consists of red and

white sandstones, with red clays, and thin limestones, the whole attaining a thickness of about 1500 feet. The term "marl" is very generally employed to designate the clays of the Lower and Upper Trias, but the term is inappropriate, as they contain no lime, and are therefore not genuine marls. In Britain the Bunter Sandstein consists of red and mottled sandstones, with unconsolidated conglomerates, or "pebble-beds," the whole having a thickness of about 1200 feet. The Bunter Sandstein, as a rule, is very barren of fossils.

II. The Middle Trias is not developed in Britain, but it is largely developed in Germany, where it constitutes what is known as the *Muschelkalk* (Germ. *Muschel*, mussel; *kalk*, limestone), from the abundance of fossil shells which it contains. The Muschelkalk consists of compact grey or yellowish limestones, sometimes dolomitic, and including occasional beds of gypsum and rock-salt.

III. The Upper Trias, or *Keuper*, as it is generally called, occurs in England; but is not so well developed as it is in Germany. In Britain the Keuper is about 1000 feet in thickness, and consists of white and brown sandstones, with red marls, the whole topped by red clays with rock-salt and gypsum.

The Keuper in Britain is extremely unfossiliferous; but it passes upwards with perfect conformity into a very remarkable group of beds, at one time classed with the Lias, and now known under the names of the Penarth beds (from Penarth, in Glamorganshire), the Rhætic beds (from the Rhætic Alps), or the *Avicula contorta* beds (from the occurrence in them of great numbers of this peculiar Bivalve). These singular beds have been variously regarded as the highest beds of the Trias, or the lowest beds of the Lias, or as an intermediate group. The phenomena observed on the Continent, however, render it best to consider them as Triassic, as they certainly agree with the so-called St Cassian or Kössen beds which form the top of the Trias in the Austrian Alps.

The Penarth beds occur in Glamorganshire, Gloucestershire, Warwickshire, Staffordshire, and the north of Ireland; and they generally consist of a small thickness of dark grey and black shales, surmounted conformably by the lowest beds of the Lias. The most characteristic fossils which they contain are the three Bivalves *Cardium Rhæticum*, *Avicula contorta*, and *Pecten Valoniensis;* but they have yielded many other fossils, amongst which the most important are the remains of Fishes and small Mammals (*Microlestes*).

In the Austrian Alps the Trias terminates upwards in an

extraordinary series of fossiliferous beds, replete with marine fossils. Sir Charles Lyell gives the following table of these remarkable deposits :—

Strata below the Lias in the Austrian Alps, in Descending Order.

1. Koessen beds. (Synonyms, Upper St Cassian beds of Escher and Merian).	Grey and black limestone, with calcareous marls having a thickness of about 50 feet. Among the fossils, Brachiopoda very numerous; some few species common to the genuine Lias; many peculiar. *Avicula contorta*, *Pecten Valoniensis*, *Cardium Rhæticum*, *Avicula inæquivalvis*, *Spirifer Münsteri*, Dav. Strata containing the above fossils alternate with the Dachstein beds, lying next below.	
2. Dachstein beds.	White or greyish limestone, often in beds three or four feet thick. Total thickness of the formation above 2000 feet. Upper part fossiliferous, with some strata composed of corals. (*Lithodendron.*) Lower portion without fossils. Among the characteristic shells are *Hemicardium Wulferii*, *Megalodon triqueter*, and other large bivalves.	
3. Hallstadt beds (or St Cassian).	Red, pink, or white marble, from 800 to 1000 feet in thickness, containing more than 800 species of marine fossils, for the most part mollusca. Many species of *Orthoceras*. True *Ammonites*, besides *Ceratites* and *Goniatites*, *Belemnites* (rare), *Porcellia*, *Pleurotomaria*, *Trochus*, *Monotis salinaria*, &c.	
4. *A*. Guttenstein beds. *B*. Werfen beds, base of Upper Trias? Lower Trias of some geologists.	*A*. Black and grey limestone 150 feet thick, alternating with the underlying Werfen beds. *B*. Red and green shale and sandstone, with salt and gypsum.	Among the fossils are *Ceratites cassianus*, *Myacites fassaensis*, *Naticella costata*, &c.

In the United States, rocks of Triassic age occur in several areas between the Appalachians and the Atlantic seaboard; but they show no such triple division as in Germany, and their exact place in the system is uncertain. The rocks of these areas consist of red sandstones, sometimes shaly or conglomeratic, occasionally with beds of impure limestone. Other more extensive areas where Triassic rocks appear at the surface, are found west of the Mississippi, on the slopes of the Rocky Mountains, where the beds consist of sandstones and gypsiferous marls. The American Trias is chiefly remarkable for having yielded the remains of a small Marsupial (*Dromatherium*) and

numerous footprints, which have generally been referred to Birds (*Brontozoum*), along with the tracks of undoubted Reptiles (*Otozoum*, *Anisopus*, &c.)

LIFE OF THE TRIASSIC PERIOD.—The Triassic period, as regards its plants and animals, is in many respects intermediate between the Palæozoic and the later Mesozoic deposits, whilst being itself decidedly Mesozoic. Amongst the plants there are some Palæozoic types (such as *Calamites*); but there is no longer a marked predominance of Cryptogams, and the leading forms are Ferns (*Pecopteris*, *Neuropteris*, *Acrostichites*, &c.), Cycads (*Pterophyllum*, *Podozamites*, &c.), and Conifers (chiefly belonging to the genus *Voltzia*).

The *Protozoa* are represented in Triassic times by several sponges (*Amorphospongia*, *Cupulispongia*, *Leiospongia*, &c.) Corals are by no means infrequent in the Muschelkalk, and in some of the limestones of the Upper Trias; but they are otherwise rare. They belong mostly to Secondary types, such as *Montlivaltia*, *Synastræa*, *Acrosmilia*, *Eunomia*, &c. The Echinoderms are rarely abundant, but two forms are exceedingly characteristic of the Muschelkalk. These are the beautiful Lily-encrinite, *Encrinus liliiformis* (fig. 80), and the little Ophiurid, *Aspidura loricata* (fig. 71).

Articulates are not abundant, with the exception of *Ostracoda*, which are sometimes very plentiful. The other common forms are referable to *Estheria;* but Macrurous Decapods have also been detected. Besides Crustaceans, several forms of Insects have been discovered.

The *Mollusca* are exceedingly abundant in parts of the Triassic series, and they exhibit an extraordinary intermixture of Palæozoic and Mesozoic types. This is shown in a synoptical manner in the following table of the *Mollusca* of the Upper Trias of the Austrian Alps, given by Sir Charles Lyell in his 'Elements of Geology:'—

Genera of Fossil Mollusca in the St Cassian and Hallstadt Beds.

Common to Older Rocks.	Characteristic Triassic Genera.	Common to Newer Rocks.
Cyrtoceras.	Ceratites.	Ammonites.
Orthoceras.	Scoliostoma (or	Belemnites.
Goniatites.	*Cochlearia*).	Nerinæa.
Loxonema.	Naticella.	Opis.
Holopella.	Platystoma.	Cardita.
Murchisonia.	Isoarca.	Trigonia.
Euomphalus.	Pleurophorus.	Myoconchus.
Porcellia.	Myophoria.	Ostrea. 1 sp.
Megalodon.	Monotis.	Plicatula.
Cyrtia.	Koninckia.	Thecidium.

From the above table it will be seen, that amongst the *Gasteropoda* the Trias has yielded the characteristically Palæozoic *Loxonema*, *Holopella*, *Murchisonia*, and *Euomphalus*, all of which commence their existence in the Silurian period. With these are forms like *Scoliostoma* and *Platystoma*, which are characteristically Triassic, and these are associated with such a typical Jurassic genus as *Nerinæa*. Amongst the Bivalves, we find the Palæozoic *Megalodon* side by side with the Triassic *Monotis* and *Myophoria*, these being associated with the *Trigoniæ*, *Plicatulæ*, and Oysters of later deposits. The Brachiopods exhibit the Palæozoic *Cyrtia*, with the Triassic *Koninckia*, and the modern genus *Thecidium*. Lastly, amongst the Cephalopods, this same intermingling of old and new types is shown in its most striking form. The ancient genera *Orthoceras*, *Cyrtoceras*, and *Goniatites* appear here for the last time upon the scene. With these are the first Dibranchiate Cephalopods, represented by the great Mesozoic genus *Belemnites*. The *Ammonitidæ*, with the disappearance of the comparatively simple *Goniatites*, are represented by the more complex *Ceratites*, which is exclusively Triassic; whilst the still more complicated genus *Ammonites* makes its first appearance here, and is never again wanting till we reach the close of the Mesozoic period.

The *Vertebrata* are represented in the Triassic period apparently by members of all the existing classes. Fishes are very numerous, and belong chiefly to the Hybodonts, Acrodonts, and Ganoids. Amongst the more important forms we find the Palæozoic genera *Palæoniscus* and *Amblypterus*, with the Secondary *Hybodus* and *Acrodus*, and the Triassic genus *Saurichthys*. We may also assert now with tolerable safety, that the order of the Dipnoous Fishes was represented in Triassic times by various species of the genus *Ceratodus*.

The Amphibians of the Trias are known both by the actual bones and teeth, and still more commonly by their footprints. They belonged exclusively to the order of the *Labyrinthodontia*, which disappears finally at the close of this period.

Of the living orders of the Reptiles, the Chelonians are only known by more or less doubtful footprints; the Lacertilians are represented by *Telerpeton* and *Rhynchosaurus* (the last often referred to the Dicynodonts); the *Crocodilia* are represented by *Stagonolepis*, *Belodon*, *Thecodontosaurus*, and *Palæosaurus* (the last two referred by Huxley to the Deinosaurs); and the Ophidians do not appear to have yet commenced their existence. Of the extinct orders of Reptiles, the Pterosaurs are unknown in the Trias, and the Ichthyosaurs are not with cer-

tainty known to have existed. The Plesiosaurs are represented by species of *Plesiosaurus* itself, and by the allied genera *Simosaurus*, *Nothosaurus*, *Pistosaurus*, &c. The *Anomodontia* are represented by the genera *Dicynodon* and *Oudenodon;* whilst *Rhynchosaurus* is referred by Owen to this group. Lastly, the Deinosaurs are represented, according to Huxley, by several forms, amongst which the most important are the "Thecodont" *Palæosaurus* and *Thecodontosaurus*, both of which have been referred by other writers to different groups of the *Reptilia.*

The existence of Birds during the Triassic period must, as yet, be regarded as uncertain. The only evidence as to their existence which has been hitherto obtained, consists in the paired footprints which have been already spoken of as occurring in the Triassic strata of the Connecticut Valley. These footprints are very numerous, and are often of very large size; and there is no doubt but that many of them were produced by animals walking upon two legs. Some of them, however, have been unquestionably produced by Reptiles; and it must at present remain uncertain whether all have been thus formed, or whether some may not have been formed by Birds. The probabilities, however, are in favour of the view that some of these tracks are truly ornithic.

Lastly, the Mammals are represented in the Trias only by the small forms referred to the genera *Microlestes* and *Dromatherium*, both of which are probably referable to the order of the Marsupials.

CHAPTER LII.

JURASSIC PERIOD.

Rocks of the Period.

Succeeding to the Trias, we have a great series of Rocks which are known as the *Oolitic Rocks*, from their commonly containing oolitic limestones, or as the *Jurassic Series*, from their being largely developed in the mountain-range of the Jura, on the western borders of Switzerland. The Jurassic rocks are very extensively developed in Britain, where they consist of the following members in ascending order:

I. Lias.

II. Lower Oolites (consisting of the Inferior Oolite, Fuller's Earth, Great Oolite, Stonesfield Slate, &c.)

III. Middle Oolites (Oxford Clay and Coral-rag).
IV. Upper Oolites (Kimmeridge Clay, Portland Stone, and Purbeck beds).

I. The *Lias* succeeds the uppermost beds of the Trias with perfect conformity, and passes upward, generally conformably, into the lowest beds of the Lower Oolites. It consists essentially of a great series of bluish or greyish laminated clays, alternating with thin bands of blue or grey limestone, the whole assuming at a distance a characteristically striped and banded appearance.

II. The *Lower Oolites* consist of calcareous freestones (Inferior Oolite), shales, clays, and marls (Fuller's earth), fine-grained Oolitic limestones (Great Oolite), with calcareous flags at the base (Stonesfield slate), and superiorly shelly limestones and calcareous sandstones (Forest-marble and Cornbrash), the whole having a thickness of from 400 to 500 feet. In Yorkshire the Lower Oolites consist of limestones with carbonaceous shales and thin seams of coal, which are sufficiently extensive and constant to be worked for coal. Of this age, also, is probably the coal-field of Brora, in Sutherlandshire, in the north of Scotland.

III. The *Middle Oolites* are composed of a great mass of dark-blue tenacious clay (Oxford clay), with a maximum thickness of 700 feet, surmounted by from 150 to 250 feet of limestones, known as the Coral-rag, from the number of corals contained in them.

IV. The *Upper Oolites* consist in Britain of laminated, sometimes carbonaceous or bituminous clays (Kimmeridge clay), forming the base of the group, and having a thickness of 500 or 600 feet. These are succeeded by sandstones and limestones (Portland stone) of about 120 feet in thickness; and the formation is capped by a remarkable group of alternating strata of fresh-water, brackish-water, and marine beds, with old land-surfaces, the whole known as the Purbeck beds, and having a united thickness of about 150 feet. Of the same age as the Upper Oolites in Britain is the Solenhofen slate of Bavaria, an exceedingly fine-grained stone, which is largely used in lithography, and is celebrated for the number and beauty of its organic remains, especially those of Vertebrates.

Rocks belonging to the Jurassic series, in the form of limestones and marls, have been detected by their fossils in the Laramie Mountains and in other portions of the Rocky Mountains, and also at various points in Arctic America. The extent, however, of these beds is unknown, and no subdivisions have hitherto been established in them.

LIFE OF THE PERIOD. — The vegetation of the Jurassic period is characterised by the abundance of Ferns, Cycads, and Conifers—the *Cycadaceæ* attaining here their maximum of development.

The *Protozoa* are represented by numerous *Foraminifera* and by Sponges. Of the former the genera *Involutina*, *Nodosaria*, *Cristellaria*, *Dentalina*, and *Frondicularia* may be mentioned as amongst the most important. Of the latter the chief forms belong to *Cribrospongia*, *Actinospongia*, *Porospongia*, *Goniospongia*, *Perispongia*, *Chenendopora*, and *Scyphia*.

The Cœlenterates are represented in the Jurassic period by numerous corals, which are exceedingly abundant in some of the limestones of the series (such as the Coral-rag and the Great Oolite). The number of Oolitic genera of Corals is very large, but the commonest and most characteristic forms belong to *Thamnastræa*, *Isastræa*, *Prionastræa*, *Anabacia*, *Montlivaltia*, *Thecosmilia*, *Eunomia*, *Protoseris*, *Comoseris*, *Dendrarea*, *Dactylarea*, *Lobocœnia*, *Aplophyllia*, *Trochocyathus*, and *Stylina*.

The Echinoderms are very largely represented all through the Jurassic Series. The Crinoids are represented both by stalked forms (*Pentacrinus*, *Extracrinus*, *Apiocrinus*, &c.) and by free forms (*Saccosoma*). Echinoids are extremely abundant in many parts of the series, the commonest generic types being *Hemicidaris*, *Diadema*, *Pseudodiadema*, *Nucleolites*, *Dysaster* (*Collyrites*), *Acrosalenia*, and *Cidaris*. True Star-fishes (*Uraster*, *Tropidaster*, *Plumaster*, *Solaster*, and *Astropecten*) are not unknown, and *Ophiuroids* (*Ophioderma*, *Ophiolepis*, *Acroura*, &c.) are far from uncommon.

As regards the Arthropods, Crustaceans are abundantly found in certain beds (especially in the Solenhofen Slates). The orders which are most largely represented are the *Decapoda* (with many forms, both Macrurous and Brachyurous), the *Cirripedia*, and the *Ostracoda*. Besides Crustaceans, the Oolitic rocks have yielded numerous Insects, belong to the orders *Coleoptera*, *Neuroptera*, *Orthoptera*, *Hemiptera*, *Diptera*, and *Hymenoptera*. True Spiders have also been detected.

Coming to the *Mollusca*, Brachiopods are still abundant, though they do not fill such a predominant place in the marine fauna as in many Palæozoic deposits. The Palæozoic genera *Leptæna* and *Spirifera* appear here (in the Lias) for the last time; and most of the Jurassic forms belong to the modern genera *Terebratula* and *Rhynchonella*. Bivalves are very abundant, and approximate in many respects to existing forms. The sub-genera *Gryphæa* and *Exogyra* amongst the Oysters,

along with numerous forms of *Ostrea* itself, and the genera *Trigonia*, *Lima* (*Plagiostoma*), *Pholadomya*, *Cardinia*, and *Avicula* may be mentioned as comprising most of the commoner forms. One of the most remarkable, however, of the Oolitic genera of Lamellibranchs is *Diceras* (fig. 189), comprising certain singular shells allied to the existing *Chama*. These are so abundant in a limestone of the Alps of the age of the Coral-rag as to have gained for this formation the name of "Diceras Limestone."

Of the *Gasteropoda* there are many examples of the ancient genus *Pleurotomaria;* but on the whole the Univalves have a modern aspect. Holostomatous Univalves, such as *Nerita*, *Patella*, *Natica*, *Turritella*, *Chemnitzia*, and *Nerinæa*, still hold a predominant place; and species of the last-named genus are especially characteristic of parts of the series. The Tertiary and modern genus, *Cerithium*, also makes its first appearance here. Though the *Holostomata* still predominate, there is now a fair proportion of the carnivorous siphonostomatous Univalves, and many of these are referable to existing genera. Thus, with the extinct *Purpuroidea* are found forms belonging to such genera as *Pteroceras*, *Rostellaria*, *Buccinum*, *Fusus*, *Murex*, and *Pleurotoma*. The *Cephalopoda* are exceedingly abundant all through the Jurassic series, and are represented by both Dibranchiate and Tetrabranchiate types. The Dibranchiate *Belemnitidæ* here attained their maximum of development, many beds being literally charged with the guards of these extinct cuttle-fishes. The Tetrabranchiates are represented by various species of the persistent genus *Nautilus*, but more especially by species of *Ammonites*, which are extraordinarily plentiful and of the most varied forms. Speaking generally, Ammonites and Belemnites may be stated to be *the* characteristic fossils of the Jurassic period.

In the fresh-water strata of the Oolites (Purbeck beds), the Molluscs, as a matter of course, belong to forms which now inhabit fresh water. Thus, amongst the Bivalves we have the genus *Cyrena*, and amongst the Gasteropods we meet with the genera *Planorbis*, *Physa*, *Paludina*, and *Melanopsis*. As regards the Vertebrates, little need be said about the Jurassic fishes, which belong to the *Ganoidei* and *Elasmobranchii*. The Ganoids now possess, many of them, symmetrical tails, and the most important genera are *Tetragonolepis*, *Dapedius*, *Æchmodus*, *Pycnodus*, *Leptolepis*, and *Aspidorhynchus*. The *Cestraphori* are represented by Hybodonts (*Hybodus* and *Strophodus*) and *Acrodus*. Lastly, the true Sharks are not without Jurassic representatives (*Notidanus*).

The *Reptilia* have an enormous development in Oolitic times, and are represented both by forms allied to those now in existence and by types which are now altogether extinct. Of the living forms there are as yet no Ophidians, but the Chelonians are represented by various genera (*Idiochelys*, *Eurysternum*, and *Chelone*). The Lacertilians are represented by several forms of no special importance, and the *Crocodilia* were represented by species with amphicœlous vertebræ (*Teleosaurus* and *Steneosaurus*). Of the extinct orders of Reptiles, the *Ichthyopterygia*, comprising only the genus *Ichthyosaurus*, form a very marked feature in the Reptilian fauna of the Jurassic period. Numerous species of *Ichthyosaurus* are known; and the remains of individuals are very abundant in certain beds, especially in the Lias. The *Sauropterygia* are represented by numerous species of *Plesiosaurus*, remains of which are also very abundant in the Lias and in other parts of the Oolitic series. The *Pterosauria* are represented by all their chief genera (*Pterodactylus*, *Dimorphodon*, and *Ramphorhynchus*); and though commencing in the Lias, they are most abundant in the Solenhofen Slate. The Dicynodonts appear to have died out; but the Deinosaurs are largely represented, chiefly by the genera *Megalosaurus* and *Cetiosaurus*.

The Birds have no other representative in the Oolitic period than the extraordinary *Archæopteryx macrura* of the Solenhofen Slates—the first undoubted indication of birds in the geological record. As has been before pointed out, this Jurassic bird differed in several most important characters from all known members of the class, whether living or extinct; its most striking peculiarity being the possession of a long, lizard-like tail composed of free vertebræ, of which each supported a pair of quill-feathers.

The Mammals, taking all things into consideration, are well represented in the Jurassic series, their remains belonging to the two horizons of the Stonesfield Slate (Lower Oolites) and the Purbeck beds (Upper Oolites). The Stonesfield Mammals—viz., *Amphitherium*, *Amphilestes*, *Phascolotherium*, and *Stereognathus*—are all of small size; and the first three appear to be certainly Marsupial. *Stereognathus* may be also a Marsupial, but its true affinities are uncertain. The Purbeck Mammals—*Triconodon*, *Spalacotherium*, *Galestes*, and *Plagiaulax*—were likewise all of small size, and they appear to have been all Marsupial; the three first-named being probably insectivorous, whilst the last appears to have been a vegetable-feeder.

CHAPTER LIII.

CRETACEOUS PERIOD.

Rocks of the Period.

The next series of rocks in ascending order is the great and important series of the *Cretaceous Rocks*, so called from the general occurrence in the system of chalk (Lat. *creta*, chalk). As developed in Britain and Europe generally, the following leading subdivisions may be recognised in the Cretaceous series :—

1. Wealden,	Lower Cretaceous.
2. Lower Greensand or Neocomian,	
3. Gault,	Upper Cretaceous.
4. Upper Greensand,	
5. Chalk,	
6. Maestricht beds,	

I. The *Wealden* formation, though of considerable importance, is a local group, and is confined to the south-east of England, France, and some other parts of Europe. Its name is derived from the *Weald*, a district comprising parts of Surrey, Sussex, and Kent, where it is largely developed. Its lower portion, for a thickness of from 500 to 1000 feet, is arenaceous, and is known as the Hastings Sands. Its Upper portion, for a thickness of 150 to nearly 300 feet, is chiefly argillaceous, consisting of clays with sandy layers, and occasionally courses of limestone. The geological importance of the Wealden formation is very great, as it is undoubtedly the delta of an ancient river, being composed almost wholly of fresh-water beds, with a few brackish-water and even marine strata, intercalated in the lower portion. Its geographical extent, though uncertain, owing to the enormous denudation to which it has been subjected, is nevertheless great, since it extends from Dorsetshire to France, and occurs also in North Germany. Still, even if it were continuous between all these points, it would not be larger than the delta of such a modern river as the Ganges. The river which produced the Wealden series must have flowed from an ancient continent occupying what is now the Atlantic Ocean ; and the time occupied in the formation of the Wealden must have been very great, though we have, of course, no data by which we can accurately calculate its duration.

The fossils of the Wealden series are, naturally, mostly the remains of such animals as we know at the present day as inhabiting rivers. We have, namely, fresh-water mussels (*Unio*), river-snails (*Paludina*), and other fresh-water shells, with numerous little bivalved Crustaceans, and some fishes.

II. The Wealden beds pass upward, often by insensible gradations, into the *Lower Greensand*. The name Lower Greensand is not an appropriate one, for green sands only occur sparingly and occasionally, and are found in other formations. For this reason it has been proposed to substitute for Lower Greensand the name *Neocomian*, derived from the town of Neufchâtel—anciently called *Neocomum*—in Switzerland. If this name were adopted, as it ought to be, the Wealden beds would be called the Lower Neocomian.

The Lower Greensand or Neocomian of Britain has a thickness of about 850 feet, and consists of alternations of sands, sandstones, and clays, with occasional calcareous bands. The general colour of the series is dark brown, sometimes red, and the sands are occasionally green, from the presence of silicate of iron.

The fossils of the Lower Greensand are purely marine, and among the most characteristic are the shells of *Cephalopods*.

The most remarkable point, however, about the fossils of the Lower Cretaceous series, is their marked divergence from the fossils of the Upper Cretaceous rocks. Of 280 species of fossils in the Lower Cretaceous series, only 51, or about 18 per cent, pass on into the Upper Cretaceous. This break in the life of the two periods is accompanied by a decided physical break as well, for the Gault is often, if not always, unconformably superimposed on the Lower Greensand. At the same time, the Lower and Upper Cretaceous groups form a closely-connected and inseparable series, as shown by a comparison of their fossils with those of the underlying Jurassic Rocks and the overlying Tertiary beds. Thus, in Britain no marine fossil is known to be common to the marine beds of the Upper Oolites and the Lower Greensand; and of more than 500 species of fossils in the Upper Cretaceous Rocks, almost every one died out before the formation of the lowest Tertiary strata, the only survivors being one Brachiopod and a few *Foraminifera*.

III. The lowest member of the Upper Cretaceous series is a stiff, dark-grey, blue, or brown clay, often worked for brickmaking, and known as the *Gault*, from a provincial English term. It occurs chiefly in the south-east of England, but can be traced through France to the flanks of the Alps and Ba-

varia. It never exceeds 100 feet in thickness; but it contains many fossils, usually in a state of beautiful preservation.

IV. The Gault is succeeded upward by the *Upper Greensand*, which varies in thickness from three up to 100 feet, and which derives its name from the occasional occurrence in it of green sands. These, however, are local and sometimes wanting, and the name "Upper Greensand" is to be regarded as a *name* and not a description. The group consists, in Britain, of sands and clays, sometimes with bands of calcareous grit or siliceous limestone, and occasionally containing concretions of phosphate of lime, which are largely worked for agricultural purposes.

V. The top of the Upper Greensand becomes argillaceous, and passes up gradually into the base of the great formation known as the true *Chalk*, divided into the three subdivisions of the chalk-marl, white chalk without flints, and white chalk with flints. The first of these is simply argillaceous chalk, and passes up into a great mass of obscurely-stratified white chalk in which there are no flints. This, in turn, passes up into a great mass of white chalk, in which the stratification is marked by nodules of black flint arranged in layers. The thickness of these three subdivisions taken together is sometimes over 1000 feet, and their geographical extent is very great. White Chalk, with its characteristic appearance, may be traced from the north of Ireland to the Crimea, a distance of about 1140 geographical miles, and, in an opposite direction, from the south of Sweden to Bordeaux, a distance of about 840 geographical miles.

VI. In Britain there occur no beds containing Chalk fossils, or in any way referable to the Cretaceous period, above the true White Chalk with flints. On the banks of the Maes, however, near Maestricht, in Holland, there occurs a series of yellowish limestones, of about 100 feet in thickness, and undoubtedly superior to the White Chalk. These *Maestricht beds* contain a remarkable series of fossils, the characters of which are partly Cretaceous and partly Tertiary. Thus, with the characteristic Chalk fossils, *Belemnites*, *Baculites*, Sea-Urchins, &c., are numerous Univalve Molluscs, such as Cowries and Volutes, which are otherwise exclusively Tertiary or Recent.

Holding a similar position to the Maestricht beds, and showing a similar intermixture of Cretaceous forms with later types, are certain beds which occur in the island of Seeland, in Denmark, and which are known as the *Faxöe Limestone.*

VII. In North America, the Lower Cretaceous Rocks are

not represented at all, or very feebly; but there is a very extensive development of rocks of Upper Cretaceous age in the United States. According to Dana, "the Cretaceous Rocks occur—1. At intervals along the *Atlantic border*, south of New York, from New Jersey to South Carolina; 2. Extensively over the States along the *Gulf border*; and 3. Through a large part of the *Western interior region*, over the slopes of the Rocky Mountains, from Texas northward, to the head-waters of the Missouri on the east of the summit of the chain, and far into the Colorado region on the west. Still farther north-west in British America, they appear on the Saskatchewan and Assiniboine, and also on the Arctic Sea, near the mouth of the Mackenzie." The rocks of these areas consist chiefly of sands, marls, clays, and limestones; but it is to be remembered that there is no white *Chalk*. Green sands are often present, as in New Jersey, where they are called "marls," and are largely worked for agricultural purposes, their fertilising properties being due to the presence of a small percentage of phosphate of lime.

LIFE OF THE CRETACEOUS PERIOD.—As regards the vegetation of the Cretaceous period, the plants of the Inferior division of the series agree with those of the antecedent Jurassic period in consisting chiefly of Ferns, Cycads, and Conifers. In the Upper Cretaceous Rocks, on the other hand, we find a vegetation composed largely of Angiospermous Exogens, many of which belong to existing genera.

The *Protozoa* are very largely represented in the Cretaceous period by *Foraminifera* and Sponges. The microscopic shells of the former are often excessively abundant; and the white chalk is to a large extent composed of the *exuviæ* of these minute organisms. Amongst the more important genera may be mentioned *Textularia*, *Globigerina*, *Rotalia*, *Lituola*, *Nodosaria*, *Flabellina*, *Cuneolina*, *Cristellaria*, *Bulimina*, *Dentalina*, &c. Sponges are very numerous, especially in the Upper Greensand and White Chalk. The most important genera are *Siphonia*, *Ventriculites*, *Manon*, *Choanites*, *Cliona*, *Scyphia*, *Chenendopora*, *Guettardia*, and *Polypothecia;* but many other forms might be mentioned.

The Cœlenterates are represented by Corals, belonging mainly to the genera *Trochocyathus*, *Cyclocyathus*, *Trochosmilia*, *Parasmilia*, *Cyathina*, *Micrabacia*, *Stephanophyllia*, &c. In the Upper Greensand, also, occurs the little *Holocystis elegans*, long believed to be the last of the Rugose Corals.

The Echinoderms are exceedingly abundant in the Cretaceous rocks, but belong mainly to the Echinoids. Crinoids,

though not altogether rare, are very perceptibly reduced in numbers, the more important forms being *Marsupites*, *Pentacrinus*, *Bourgueticrinus*, and *Comatula*. Sea-urchins, on the other hand, are so numerous as to constitute one of the most marked features in the Cretaceous fauna. The leading genera are *Micraster*, *Ananchytes*, *Galerites*, *Hemipneustes*, *Diadema*, *Discoidea*, *Salenia*, *Cidaris*, *Catopygus*, *Pygaster*, *Pygaulus*, *Holaster*, &c.

The Arthropods are represented by various Crustaceans belonging mainly to the Macrurous and Brachyurous Decapods, and to the Cirripedes. The little Ostracodes are also abundant in many parts of the series, especially in the fresh-water strata of the Wealden.

Coming to the *Mollusca*, the *Polyzoa* have a great development in the Cretaceous deposits, the family of the *Escharidæ* here attaining its maximum. Amongst the more characteristic Cretaceous genera may be mentioned *Eschara*, *Escharina*, *Vincularia*, *Membranipora*, *Flustra*, *Reticulipora*, *Hornera*, *Tubulipora*, &c.

Brachiopods are not especially numerous, and belong mainly to *Terebratula*, *Terebratella*, *Terebratulina*, *Rhynchonella*, and *Crania*. Bivalves are very abundant, and some of them are very characteristic. Amongst these are numerous species of *Ostrea*, *Exogyra*, *Lima*, *Plicatula*, *Pecten*, and *Spondylus*, with the various species of *Inoceramus*, and the great family of the *Hippuritidæ*. With the exception of a few Jurassic species, the genus *Inoceramus* is exclusively Cretaceous, being represented in deposits of this period by numerous species, and not being known to have survived it. The *Hippuritidæ*, or *Rudistes* of Lamarck, comprise a great number of very aberrant Bivalves, all of which were attached and lived associated in beds, like Oysters. The two valves of the shell are always unlike in sculpturing, in appearance, and in shape, and the cast of the interior is often very unlike the form of the outer surface of the shell. A great many species of this family are known, chiefly referable to the genera *Hippurites*, *Radiolites*, and *Caprina*. The family appears to be exclusively Cretaceous ; and the most characteristic members of the Cretaceous series of the south of Europe consists of certain compact marbles, which are known as " Hippurite Limestone," from the abundance of shells of this family.

Gasteropods are not particularly numerous in the Cretaceous Rocks, and belong chiefly to such modern genera as *Turritella*, *Natica*, *Solarium*, *Scalaria*, *Rostellaria*, *Dentalium*, *Phorus*, &c. Along with these are species of the persistent genus *Pleu-*

rotomaria, and the Mesozoic *Nerinæa*. Towards the close of the Cretaceous period, we meet for the first time with Gasteropods of the existing genera *Voluta*, *Mitra*, *Cypræa*, *Fasciolaria*, *Strombus*, &c.

The most characteristic Molluscs of the Cretaceous period are Cephalopods. The Dibranchiate section of this order is represented by species of *Belemnites* itself and by the genus *Belemnitella*. Of the Tetrabranchiates we find species of the old genus *Nautilus;* but this section is represented mainly by complex and beautiful forms of the *Ammonitidæ*. The genus *Ammonites* itself, dating its existence from the Upper Trias, is represented by many Cretaceous species, and finally disappears with the close of this period. *Ancyloceras* dates from the commencement of the Jurassic period, and also dies out in the Chalk. Finally, the *Ammonitidæ* are represented by the genera *Baculites*, *Turrilites*, *Scaphites*, *Hamites*, *Ptychoceras*, *Toxoceras*, and *Crioceras*, which make their first appearance in the Cretaceous rocks, but which are not known at present to occur in any later deposit.

Remains of Fishes are by no means rare in the Cretaceous rocks. Teleostean Fishes appear here, and are well represented by forms more or less allied to existing types (*Beryx*, *Osmeroides*, &c.) Ganoids (such as *Lepidotus*, *Caturus*, *Pycnodus*, &c.) are plentiful; but are of little special importance. Of the Cestracionts, we have the old genus *Acrodus*, and the Cretaceous genus *Ptychodus*. Hybodonts also occur, and teeth of true Selachians (*Lamna*, *Carcharias*, *Odontaspis*, &c.) are not wanting.

The Reptiles of the Cretaceous belong mostly to the orders of the *Pterosauria*, *Ichthyopterygia*, *Sauropterygia*, and *Deinosauria*—all of which die out with the Cretaceous period. The best known of the Deinosaurs is *Iguanodon*, which is confined exclusively to the Lower Cretaceous period, but the genera *Ichthyosaurus*, *Plesiosaurus*, and *Pterodactylus*, extend their range into the Upper Cretaceous. The only exclusively Cretaceous group of Reptiles is that of the *Mosasauroids*, which are known to have existed up to the last phase of this period (Maestricht beds). The Mosasauroids are found in Europe, but more abundantly in North America; and the recent discovery by Professor Marsh, that the body was, in some cases, furnished with a covering of bony scutes, would seem to remove them from the Lizards, amongst which they have been generally placed.

Birds have not been shown with certainty to have existed during the Cretaceous period in Europe, though various re-

mains of this age have been with more or less probability regarded as being Ornithic. The Upper Cretaceous rocks of the United States have, however, yielded the remains of undoubted birds (*Laornis*, *Telmatornis*, *Scolopax*, and *Palæotringa*). More remarkable than any of the above are the recently-discovered *Hesperornis* and *Ichthyornis*, of which the former is a large Diver-like bird, whilst the latter exhibits the singular peculiarity that the vertebræ are biconcave. Mammals have not hitherto been detected in any Cretaceous deposit.

CHAPTER LIV.

EOCENE PERIOD.

BEFORE commencing the study of the subdivisions of the Kainozoic series, there are some general considerations to be noted. In the first place, there is a complete and entire physical break between the rocks of the Mesozoic and Kainozoic periods. In no instance are Tertiary strata to be found resting conformably upon any Secondary rock. The Chalk has invariably suffered much erosion and denudation before the lowest Tertiary strata were deposited upon it. This is shown by the fact that the actually eroded surface of the Chalk can often be seen, or, failing this, that we can point to the presence of the chalk-flints in the Tertiary strata. This last, of course, affords unquestionable proof that the Chalk must have been subjected to enormous denudation prior to the formation of the Tertiary beds, all the chalk itself having been removed, and nothing left but the flints, while these are all rolled and rounded.

In the second place, there is a complete break in the *life* of the Mesozoic and Kainozoic periods. With the exception of a few *Foraminifera*, and one *Brachiopod* (the latter doubtful), no Cretaceous *species* is known to have survived the Cretaceous period ; while several characteristic *families*, such as the *Ammonitidæ* and *Hippuritidæ*, died out entirely with the close of the Cretaceous rocks. In the Tertiary rocks, on the other hand, not only are all the animals and plants more or less like existing types, but we meet with a constantly-increasing number of *living species* as we pass from the bottom of the Kainozoic series to the top. Upon this last fact is founded

the modern classification of the Kainozoic rocks, propounded by Sir Charles Lyell.

It follows from the constant want of conformity between the Cretaceous and Tertiary rocks, and still more from the entire difference in life, that the Cretaceous and Tertiary periods are separated by an enormous lapse of unrepresented time. How long this interval may have been, we have no means of judging exactly, but it very possibly was as long as the whole Kainozoic epoch itself. Some day we shall doubtless find, at some part of the earth's surface, strata which were deposited during this period, and which will contain fossils intermediate in character between the organic remains which respectively characterise the Secondary and Tertiary periods. At present, we have only slight traces of such deposits, as, for instance, the Maestricht beds.

Classification of the Tertiary Rocks.—The classification of the Tertiary rocks is a matter of unusual difficulty, in consequence of their occurring in disconnected basins, forming a series of detached areas, which hold no relations of superposition to one another. The order, therefore, of the Tertiaries in point of time, can only be determined by an appeal to fossils; and in such determination Sir Charles Lyell proposed to take as the basis of classification the *proportion of living or existing species of Mollusca which occurs in each stratum or group of strata.* Acting upon this principle, Sir Charles Lyell divides the Tertiary series into four groups:—

I. The *Eocene* formation (Gr. *eos*, dawn; *kainos*, new), containing the smallest proportion of existing species, and being, therefore, the oldest division. In this classification only the *Mollusca* are taken into account; and it was found that of these about three and a half per cent were identical with existing species.

II. The *Miocene* formation (Gr. *meion*, less; *kainos*, new), with more recent species than the Eocene, but *less* than the succeeding formation, and less than one-half the total number in the formation. As before, only the *Mollusca* are taken into account, and about 17 per cent of these agree with existing species.

III. The *Pliocene* formation (Gr. *pleion*, more; *kainos*, new), with *more* than half the species of shells identical with existing species; the proportion of these varying from 35 to 50 per cent in the lower beds of this division, up to 90 or 95 per cent in its higher portion.

IV. The *Post-Tertiary Formations*, in which *all the shells belong to existing species.* This, in turn, is divided into two

minor groups—the *Post-Pliocene* and *Recent Formations*. In the *Post-Pliocene* formations, while all the *Mollusca* belong to existing species, most of the *Mammals* belong to extinct species. In the *Recent* period, the quadrupeds, as well as the shells, belong to living species.

The above, with some modifications, was the original classification proposed by Sir Charles Lyell for the Tertiary rocks, and now universally accepted. More recent researches, it is true, have somewhat altered the proportions of existing species to extinct, as stated above. The general principle, however, of an increase in the number of living species, still holds good; and this is as yet the only satisfactory basis upon which it has been proposed to arrange the Tertiary deposits.

Eocene Formation.

The Eocene rocks are the lowest of the Tertiary series, and comprise all those Tertiary deposits in which there is only a small proportion of existing *Mollusca*—from three and a half to five per cent. The Eocene rocks occur in several basins in Britain, France, the Netherlands, and other parts of Europe, and in the United States. The subdivisions which have been established are extremely numerous, and it is often impossible to parallel those of one basin with those of another. It will be sufficient, therefore, to accept the division of the Eocene formation into three great groups—Lower, Middle, and Upper Eocene—and to consider some of the more important beds comprised under these heads in Europe and in North America.

I. Lower Eocene. — The base of the Eocene series in Britain is constituted by about 90 feet of light-coloured, sometimes argillaceous sands (Thanet Sands), which are of marine origin. Above these, or forming the base of the formation where these are wanting, come mottled clays and sands with lignite (Woolwich and Reading series), which are estuarine or fluvio-marine in origin. The highest member of the Lower Eocene of Britain is the "London Clay," consisting of a great mass of dark-brown or blue clay, sometimes with sandy beds, or with layers of "septaria," the whole attaining a thickness of from 200 to as much as 500 feet. The London Clay is a purely marine deposit, containing many marine fossils, with the remains of terrestrial animals and plants; all of which indicate a high temperature of the sea and tropical or subtropical conditions of the land.

II. Middle Eocene.—The inferior portion of the Middle Eocene of Britain consists of marine beds, chiefly consisting

of sands, clays, and gravels, and attaining a very considerable thickness (Bagshot and Bracklesham beds). The superior portion of the Middle Eocene of Britain, on the other hand, consists of deposits which are almost exclusively fresh-water or brackish-water in origin (Headon and Osborne series).

The chief Continental formations of Middle Eocene age are the "Calcaire grossier" of the Paris basin, and the "Nummulitic Limestone" of the Alps.

III. Upper Eocene.—If the Headon and Osborne beds of the Isle of Wight be placed in the Middle Eocene, the only British representatives of the Upper Eocene are the Bembridge and Hempstead beds—though the latter are regarded by Sir Charles Lyell as being of Lower Miocene age. These strata consist of limestones, clays, and marls, which have for the most part been deposited in fresh or brackish water.

IV. Eocene Beds of the Paris Basin. — The Eocene strata are very well developed in the neighbourhood of Paris, where they occupy a large area or basin scooped out of the Chalk. The beds of this area are partly marine, partly fresh-water in origin; and the following table (after Sir Charles Lyell) shows their subdivisions and their parallelism with the English series :—

General Table of French Eocene Strata.

French Subdivisions.	*English Equivalents.*
UPPER EOCENE.	
A. 1. Gypseous series of Montmartre.	1. Bembridge series.
A. 2. Calcaire silicieux, or Travertin Inférieur.	2. Osborne and Headon series.
A. 3. Grès de Beauchamp, or Sables Moyens.	3. White sand and clay of Barton Cliff, Hants.
MIDDLE EOCENE.	
B. 1. Calcaire Grossier.	1. Bagshot and Bracklesham beds.
B. 2. Soissonnais Sands, or Lits Coquilliers.	2. Wanting.
LOWER EOCENE.	
C. 1. Argile de Londres at base of Hill of Cassel, near Dunkirk.	1. London Clay.
C. 2. Argile plastique and lignite.	2. Plastic clay and sand with lignite (Woolwich and Reading series).
C. 3. Sables de Bracheux.	3. Thanet sands.

V. Eocene Strata of the United States.—In North America, Lower Eocene Rocks are extensively developed at

Claiborne, Alabama, and consist of clays, lignites, marls, and impure limestones. The fossils of the Claiborne series are much the same in their characters as those of the London clay, and the lignites contain numerous plant-remains.

The Middle Eocene group is represented in North America by lignitic clays and marls which occur at Jackson, Mississippi. Amongst the more remarkable fossils of the Jackson beds are the teeth and bones of Cetaceans of the genus *Zeuglodon*.

Rocks of Upper Eocene age occur in North America at Vicksburg, Mississippi, and consist of lignites, clays, marls, and limestones. On the White River they are about 1000 feet thick, and consist of clays, sandstones, and limestones, of fresh-water origin. Among their most remarkable fossils are the remains of Mammals, of which about forty species have been already determined.

Life of the Eocene Period.

Little need be added here as to the life of the Eocene period, fossils being so abundant as to render it impossible to do more than indicate some general considerations. Upon the whole, the plants and animals of the Eocene period closely resemble those now in existence upon the globe; not, however, necessarily in the exact localities in which they are now found. Thus, the modern representatives of the plants and animals of the Eocene Rocks of Europe are not to be found in Europe itself, but in some tropical or sub-tropical region. The climatic conditions of Europe in the Eocene period were very different to those at present subsisting, and the animals and plants were correspondingly different. Still, there are few Eocene fossils which have not their modern representatives in warm countries.

The *Protozoa* are represented in Eocene times chiefly by *Foraminifera*, which are often extraordinarily abundant, and the shells of which may in some cases be said without exaggeration to compose whole mountain-masses. The great and widespread formation of the Nummulitic Limestone is largely made up of the shells of *Nummulites* and *Orbitoides*, some of the former occasionally reaching a size of more than an inch in diameter. One of the limestones of the Paris basin is largely composed of the shells of a species of *Miliola*. Numerous other forms occur; and the genus *Nummulites* is exclusively confined to this formation.

Corals are not particularly abundant in the Eocene rocks, but they are mostly of types identical with, or nearly allied to,

those now existing. The *Tabulata* are represented by no more than one genus, and the Eocene forms belong mainly to the *Zoantharia*, *Aporosa*, and *Perforata*. Besides *Zoantharia*, the family of the *Pennatulidæ* (Sea-pens, &c.) is represented by the genus *Graphularia*, and the family of the *Gorgonidæ* (sea-shrubs), by the genera *Mopsea* and *Websteria*.

As regards the *Mollusca*, Brachiopods and *Polyzoa* are not abundant, and the former are represented in Eocene times chiefly by the existing genera *Terebratula* and *Rhynchonella*. Lamellibranchs and Gasteropods, the latter especially, are exceedingly abundant, and almost all existing genera are now represented; though less than five per cent are identical with existing *species*. The Gasteropods are chiefly siphonostomatous, and belong to such familiar genera as *Voluta*, *Mitra*, *Conus*, *Pleurotoma*, *Fusus*, *Cypræa*, *Oliva*, *Ancillaria*, *Rostellaria*, &c. The fresh-water and brackish-water beds of the formation have also yielded numerous species of *Cerithium*, along with *Limnæa*, *Planorbis*, *Melania*, &c. The *Ammonites*, *Turrilites*, *Baculites*, *Belemnites*, &c., of the Cretaceous period have now disappeared, and the *Cephalopoda* are represented mainly by the genus *Nautilus*, though Dibranchiates (such as *Belosepia*) are not unknown.

The most important fossils of the Eocene Rocks belong to the sub-kingdom of the *Vertebrata*. Fishes are numerous, sometimes (as in the limestone of Monte Bolca) extraordinarily so. They belong in the vast majority of instances to the *Teleostei*, the remains of Ganoid fishes being comparatively very rare. True Sharks are represented by numerous teeth, referable to the genera *Carcharodon*, *Otodus*, *Lamna*, *Galeocerdo*, &c.; and Rays are represented by their pavement-like dental plates (*Myliobatis*).

The Reptiles of the Eocene period all belong to the existing orders of the Chelonians, Ophidians, Lacertilians, and Crocodilians. The Chelonians are very abundant, and belong for the most part to existing genera. The Ophidians make their first appearance in the Eocene (*Palæophis*). The Crocodilians, lastly, are very abundant, speaking comparatively; and England possessed in Eocene times representatives of the three existing genera of this order—viz., *Crocodilus*, *Alligator*, and *Gavialis*.

As regards the Birds, it is sufficient to say that all the existing orders of *Aves* appear to have been represented in Eocene times, often by forms which differ little from existing types.

As regards the Mammals, the Eocene deposits have yielded remains of *Marsupialia*, *Sirenia*, *Cetacea*, *Ungulata*, *Carnivora*,

Cheiroptera, *Rodentia*, and *Insectivora*. No traces, however, have hitherto been found in the Eocene of the orders *Proboscidea* and *Edentata*, and the *Quadrumana* are represented only by two doubtful forms. The Marsupials are represented in the Eocene by *Didelphys*, the *Sirenia* by *Halitherium*, and the Cetaceans by the singular and aberrant family of the *Zeuglodonts*. The Ungulates are represented by a great series of forms, of which the most important are the two extinct groups of the *Palæotheridæ* and *Anoplotheridæ*, the former representing the Perissodactyles, the latter the Artiodactyles. Besides these, however, there occur numerous other extinct forms, chiefly referable to the genera *Coryphodon*, *Lophiodon*, *Chæropotamus*, *Anthracotherium*, *Hyopotamus*, *Pliolophus*, *Dichodon*, *Dichobune*, *Xiphodon*, &c.

The *Carnivora* are represented by the extinct *Hyænodon*, the *Cheiroptera* by species of the existing genus *Vespertilio*, the *Rodentia* by Shrew-mice (*Myoxus*), and the *Insectivora* by *Spalacodon*.

CHAPTER LV.

MIOCENE PERIOD.

Rocks of the Period.

The *Miocene* formations comprise those Tertiary deposits which contain less than about 35 per cent of existing species of *Mollusca*, and more than 5 per cent, or those deposits in which the proportion of living shells is less than of extinct species. The *Miocene* formations are divisible in Europe into a *Lower Miocene* and *Upper Miocene* group.

I. Lower Miocene.—The Miocene formations are very poorly represented in Britain, their leading development being at Bovey Tracy, in Devonshire, where there occur sands, clays, and beds of lignite or woody coal. These strata contain numerous plants, among which are Vines, Figs, the Cinnamon-tree, Palms, and a number of *Coniferæ*. Other plant-bearing strata in the Hebrides, on the west coast of Scotland, have been referred to the Miocene age.

In France, the Lower Miocene is represented in Auvergne, Cantal, and Velay, by a great thickness of nearly horizontal strata of sand, sandstone, clays, marls, and limestones, all of

fresh-water origin. Other Miocene deposits occur in Austria, Germany, Switzerland, and the Siwalik hills in India.

II. Upper Miocene.—The typical European deposits of Upper Miocene age occur in the valley of the Loire, in France, and are known as the "Faluns," a provincial term given to shelly sands employed to spread upon soils which are deficient in lime. The Faluns occur in scattered patches, which are rarely more than 50 feet in thickness, and consist of sands and marls. The fossils are chiefly marine, but there occur also land and fresh-water shells, and the remains of numerous Mammals.

In Switzerland, between the Alps and the Jura, there occurs a great series of Miocene deposits, known collectively as the "Molasse," from the soft nature of a greenish sandstone, which constitutes one of its chief members. It attains a thickness of many thousands of feet, and rises into lofty mountains, some of which—as the Rigi—are more than 6000 feet in height. The middle portion of the Molasse is of marine origin, and is shown by its fossils to be of the age of the Faluns; but the lower and upper portions of the formation are mainly or entirely of fresh-water origin. The Lower Molasse (of Lower Miocene age) has yielded about 500 species of plants, mostly of tropical or sub-tropical forms. The Upper Molasse has yielded about the same number of plants, with about 900 species of Insects, such as wood-eating Beetles, Water-beetles, White Ants, Dragon-flies, &c.

Miocene of North America.—Miocene deposits are found in the United States in New Jersey, Maryland, Virginia, California, Oregon, &c., and they attain sometimes a thickness of 1500 feet. They consist chiefly of clays, sands, and sandstones; and in Virginia there is a bed of what is wrongly called "Infusorial Earth," which attains a thickness of many feet, and consists almost wholly of the siliceous cases of certain low forms of plants (Diatoms). The strata of the White River, with remains of numerous Mammals, formerly spoken of as Upper Eocene, are sometimes referred to the Miocene formation. The fossils of the American Miocene are chiefly *Molluscs* (of which 15 to 30 per cent are living species).

Life of the Miocene Period.—The vegetation of the Miocene period has been already spoken of, and need not be again discussed here. The Invertebrates of the Miocene also need no special mention, since they are very similar in type to those now in existence, though mostly specifically distinct. The Fishes, Reptiles, and Birds of the Miocene likewise call for no special comment. The Miocene Mammals, on the

other hand, belong in great part to extinct types, and are sufficiently remarkable in their characters to demand some notice. In addition to the orders known to be represented in the Eocene Tertiary, we meet now with remains referable to the *Edentata*, *Proboscidea*, and *Quadrumana;* whilst some existing groups of the older orders are now represented for the first time.

The *Edentates* are represented by the gigantic *Macrotherium*, which appears to have been nearly allied to the Scaly Ant-eaters or Pangolins, and by the still more gigantic *Ancylotherium*.

Of the *Sirenia* we have the genus *Halitherium*, and of the true *Cetacea* we have the remains of Squalodonts and Dolphins.

Of the *Ungulates* the *Rhinoceridæ* are represented in Miocene times by *Acerotherium*, the *Equidæ* by *Anchitherium* and *Hipparion*, the *Hippopotamidæ* by species of *Hippopotamus* itself, the *Suida* by species of *Sus*, the *Moschidæ* by *Dremotherium*, the *Cervidæ* by *Dorcatherium*, the *Camelopardalidæ* by *Helladotherium*, and the *Cavicornia* by the extraordinary *Sivatherium* and *Bramatherium*. The *Bovidæ* do not appear as yet to have come into existence.

The *Proboscidea* are represented in the Miocene period by all the known sections of the order—namely, by Elephants, Mastodons, and the *Deinotherium*.

Of the *Carnivora* we have Miocene representatives of the *Felidæ* (*Machairodus*), the *Canidæ*, *Hyænidæ*, *Viverridæ*, and *Mustelidæ*. The *Insectivora* are represented by species of *Erinaceus* and *Talpa*, and the Rodents by species of *Castor*, *Mus*, *Lepus*, &c. Lastly, the *Quadrumana* are represented by the two extinct genera *Pliopithecus* and *Dryopithecus*.

CHAPTER LVI.

PLIOCENE AND POST-PLIOCENE PERIODS.

ROCKS OF THE PLIOCENE PERIOD.

THE Pliocene formations contain from 40 to 95 per cent of existing species of *Mollusca*, the remainder belonging to extinct species. They are divided by Sir Charles Lyell into two divisions, the Older Pliocene and Newer Pliocene.

The Pliocene deposits of Britain occur in Suffolk, and are known by the name of "Crags," this being a local term used

for certain shelly sands, which are employed in agriculture. Two of these Crags are referable to the Older Pliocene—viz., the White and Red Crags,—and one belongs to the Newer Pliocene, viz., the Norwich Crag.

The *White* or *Coralline Crag* of Suffolk is the oldest of the Pliocene deposits of Britain, and is an exceedingly local formation, occurring in but a single small area, and having a maximum thickness of not more than 50 feet. It consists of soft sands, with occasional intercalations of flaggy limestone. Though of small extent and thickness, the Coralline Crag is of importance from the number of fossils which it contains. The name "Coralline" is a misnomer; since there are few true Corals, and the so-called "Corals" of the formation are really *Polyzoa*, often of very singular forms. The shells of the Coralline Crag are mostly such as inhabit the seas of temperate regions; but there occur some forms usually looked upon as indicating a warm climate.

The *Upper* or *Red Crag* of Suffolk—like the Coralline Crag—has a limited geographical extent and a small thickness, rarely exceeding 40 feet. It consists of quartzose sands, usually deep red or brown in colour, and charged with numerous fossils.

Altogether more than 200 species of shells are known from the Red Crag, of which 60 per cent are referable to existing species. The shells indicate upon the whole a temperate or even cold climate, decidedly less warm than that indicated by the organic remains of the Coralline Crag. It appears, therefore, that a gradual refrigeration was going on during the Pliocene period, commencing in the Coralline Crag, becoming intensified in the Red Crag, being still more severe in the Norwich Crag, and finally culminating in the Arctic cold of the Glacial period.

Besides the *Mollusca*, the Red Crag contains the ear-bones of Whales, the teeth of Sharks and Rays, and remains of the Mastodon, Rhinoceros, and Tapir.

The *Newer Pliocene* deposits are represented in Britain by the *Norwich Crag*, a local formation occurring near Norwich. It consists of incoherent sands, loams, and gravels, resting in detached patches, from 2 to 20 feet in thickness, upon an eroded surface of Chalk. The Norwich Crag contains a mixture of marine, land, and fresh-water shells, with remains of fishes and bones of mammals; so that it must have been deposited as a local sea-deposit near the mouth of an ancient river. It contains altogether more than 100 marine shells, of which 89 per cent belong to existing species. Of the Mam-

mals, the two most important are an Elephant (*Elephas meridionalis*), and the characteristic Pliocene Mastodon (*M. Arvernensis*), which is hitherto the only Mastodon found in Britain.

The following are the more important Pliocene deposits which have been hitherto recognised out of Britain:—

1. In the neighbourhood of Antwerp occur certain "crags," which are the equivalent of the White and Red Crag in part. The lowest of these contains less than 50 per cent, and the highest 60 per cent, of existing species of shells, the remainder being extinct.

2. Bordering the chain of the Apennines, in Italy, on both sides are a series of low hills made up of Tertiary strata, which are known as the Sub-Apennine beds. Part of these is of Miocene age, part is Older Pliocene, and a portion is Newer Pliocene. The Older Pliocene portion of the Sub-Apennines consists of blue or brown marls, which sometimes attain a thickness of 2000 feet.

3. In the valley of the Arno, above Florence, are both Older and Newer Pliocene strata. The former consist of blue clays and lignites, with an abundance of plants. The latter consist of sands and conglomerates, with remains of large Carnivorous Mammals, Mastodon, Elephant, Rhinoceros, Hippopotamus, &c.

4. In Sicily, Newer Pliocene strata are probably more largely developed than anywhere else in the world, rising sometimes to a height of 3000 feet above the sea. The series consists of clays, marls, sands, and conglomerates, capped by a compact limestone, which attains a thickness of from 700 to 800 feet. The fossils of these beds belong almost entirely to living species, one of the commonest being the Great Scallop of the Mediterranean (*Pecten Jacobæus*).

5. Occupying an extensive area round the Caspian, Aral, and Azof Seas, are Pliocene deposits known as the "Aralo-Caspian" beds. The fossils in these beds are partly freshwater, partly marine, and partly intermediate in character, and they are in great part identical with species now inhabiting the Caspian. The entire formation appears to indicate the former existence of a great sheet of brackish water, forming an inland sea, like the Caspian, but as large as, or larger than, the Mediterranean.

6. In the United States, strata of Pliocene age are found in North and South Carolina. They consist of sands and clays, with numerous fossils, chiefly *Molluscs* and *Echinoderms*. From 40 to 60 per cent of the fossils belong to existing species. On the Loup Fork of the river Platte, in the Upper

Missouri region, are strata which are also believed to be referable to the Pliocene period, and probably to its upper division. They are from 300 to 400 feet thick, and contain land-shells, with the bones of numerous Mammals, such as Camels, Rhinoceroses, Mastodons, Elephants, the Horse, Stag, &c.

LIFE OF THE PLIOCENE PERIOD.—As regards the life of the Pliocene period, it is sufficient to indicate two general considerations. In the first place, we have to notice that the introduction upon the globe of existing species of animals was carried on rapidly during this period. In the older Pliocene deposits the number of shells of existing species is only from 40 to 60 per cent; but in the Newer Pliocene the proportion of existing species rises to as much as 80 to 95 per cent. The Mammals still all belong to extinct species, but modern types gradually supersede the more antique forms of the Eocene and Miocene periods. In the second place, there is good evidence to show that the Pliocene period was one in which the climate of the northern hemisphere gradually became colder. In the Miocene period, as we have seen, Europe possessed a climate probably very similar to that now enjoyed by the Southern States of the Union, and certainly very much warmer than its present climate. In the Older Pliocene, northern forms, on the other hand, predominate among the shells, though some of the types of warmer regions still survive. In the Newer Pliocene, the *Mollusca* are almost exclusively such as inhabit the seas of temperate or even cold regions. It might be thought that the occurrence of Mammals such as the Elephant, Rhinoceros, and Hippopotamus, would prove that the climate of Europe and the United States must have been a hot one during the later portion of the Pliocene period. We have, however, reason to believe that many of these extinct quadrupeds were more abundantly furnished with hair, and more adapted to withstand a cool temperature, than any of their living congeners.

Amongst the Pliocene Mammals may be mentioned the following, as comprising the more important forms:—

Mastodon Arvernensis.
Elephas meridionalis.
Elephas antiquus.
Rhinoceros megarhinus.
Hippopotamus major.
Tapirus Arvernensis.
Machairodus cultridens.
Ursus Arvernensis.
Equus plicidens.

POST-PLIOCENE PERIOD.

Later than any of the Tertiary formations are a series of deposits which are spoken of as *Post-Tertiary* or *Quaternary*, and which are characterised by the fact that all the contained

shells belong to existing species. The Post-Tertiary deposits are divided by Sir Charles Lyell into *Post-Pliocene*, in which the shells belong entirely to existing species, but *some of the Mammals are extinct;* and the *Recent*, in which the *shells and the Mammals alike belong to existing species.*

The Recent deposits do not properly concern the Palæontologist, but the Zoologist, since they contain the remains of none but existing animals. The Post-Pliocene deposits, on the other hand, contain the remains of various extinct Mammals, and therefore properly form part of the domain of the palæontologist. The deposits of the Post-Pliocene period may be divided into those which preceded the Glacial period, those which were formed during the Glacial epoch, and those which are Post-Glacial.

I. Pre-Glacial Deposits.—The chief pre-glacial deposit of Britain is found on the Norfolk coast, reposing upon the Newer Pliocene (Norwich Crag), and consists of an ancient land-surface which is known as the "Cromer Forest-bed."

This consists of an ancient soil, having embedded in it the stumps of many trees, still in an erect position, with remains of living plants, and the bones of recent and extinct quadrupeds. It is overlaid by fresh-water and marine beds, all the shells of which belong to existing species, and it is finally surmounted by true "glacial drift." While all the shells and plants of the Cromer Forest-bed and its associated strata belong to existing species, the Mammals are partly living, partly extinct. Thus, we find the existing Wolf, Bison, Reindeer, Beaver, Walrus, &c., side by side with three extinct Elephants, the Rhinoceros, and Hippopotamus, and a gigantic extinct Beaver. Among the Elephants are two Pliocene species, viz., *Elephas meridionalis* and *Elephas antiquus.* The third species is the Mammoth (*Elephas primigenius*), which has not as yet been detected in strata of Pliocene age. The following list is given by Mr Boyd Dawkins as comprising the most important Mammals as yet known in the "Forest-bed:"—

List of Pre-Glacial Mammals.

Ursus Arvernensis.	*Bos primigenius.*
Ursus spelæus (? Etruscus).	*Hippopotamus major.*
Sorex.	*Equus fossilis.*
Mygale moschata.	*Rhinoceros megarhinus.*
Talpa Europæa.	*Rhinoceros Etruscus.*
Cervus megaceros ?	*Elephas antiquus.*
Cervus capreolus.	*Elephas meridionalis.*
Cervus elaphus.	*Arvicola amphibia.*
Cervus Sedgwickii.	*Castor fiber.*
Cervus ardeus.	*Trogontherium Cuvieri.*

II. Glacial Deposits.—Under this head is included a great series of deposits which are widely spread over both Europe and America, and which were formed at a time when the climate of these countries was very much colder than it is at present, and approached more or less closely to what we see at the present day in the Arctic regions. These deposits are known by the general name of the *Glacial deposits*, or by the more specialised names of the Drift, the Northern Drift, the Boulder-clay, the Till, &c.

These glacial deposits are found in Britain as far south as the Thames, over the whole of Northern Europe, in all the more elevated portions of Southern and Central Europe, and over the whole of North America, as far south as the 39th parallel. They generally occur as sands, clays, and gravels, spread in widely-extended sheets over all the geological formations alike, except the most recent, and are commonly spoken of under the general term of "Glacial drift." They vary much in their exact nature in different districts, but they universally consist of one, or all, of the following members :—

1. *Unstratified* clays, or loams, containing numerous angular or sub-angular blocks of stone, which have often been transported for a greater or less distance from their parent rock, and which often exhibit polished, grooved, or striated surfaces. These beds are what is called *Boulder-clay*, or *Till*.

2. Sands, gravels, and clays, often more or less regularly *stratified*, but containing erratic blocks, often of large size, and with their edges *unworn*, derived from considerable distances from the place where they are now found. In these beds it is not at all uncommon to find fossil shells; and these, though of existing species, are mostly of an Arctic character, comprising a majority of forms which are now exclusively found in the icy waters of the Arctic seas. These beds are often spoken of as "Stratified Drift."

3. *Stratified* sands and gravels, in which the pebbles are *worn* and rounded, and which have been produced by a re-arrangement of ordinary glacial beds by the sea. These beds are commonly known as "Drift-gravels," or "Regenerated Drift."

The fossils of the Glacial deposits are almost exclusively shells, which belong to existing species, but are referable to species now inhabiting cold regions. The most important Glacial shells are the following :—

Pecten Islandicus.	*Trophon clathratum.*
Astarte borealis.	*Natica clausa.*
Leda oblonga.	*Scalaria Grœnlandica.*
Saxicava rugosa.	*Buccinum undatum.*
Tellina proxima.	*Purpura lapillus.*
Tellina solidula.	*Fusus Islandicus.*
Leda truncata.	*Littorina littorea.*
Astarte compressa.	

III. Post-Glacial Deposits. — Under this head are included various fluviatile deposits, such as brick-earths, low-level and high-level gravels, and all those accumulations which are generally understood by the terms "cave-deposits," "ossiferous breccias," and the like. The fossils of these deposits consist chiefly of the bones of Mammals, both living and extinct, in many instances mixed with the bones, or, more commonly, the implements of man in his earliest and rudest condition. Most of the Pre-glacial Mammals which have been previously enumerated, survived the Glacial period, and appear in Post-glacial deposits; but along with these are other forms—some extinct, some still in existence—which are not known to have lived in times prior to the Glacial epoch. The following list is given by Mr Boyd Dawkins of the Mammals which inhabited Britain during the Post-glacial epoch:—

List of Post-Glacial Mammals.

Palæolithic Man.
The Glutton (*Gulo luscus*).
The Cave Bear (*Ursus spelæus*)?
The Grizzly Bear (*Ursus ferox*)?
The Cave Lion (*Felis leo=Felis spelæa*).
The Cave Hyæna (*Hyæna spelæa*).
The Panther (*Felis pardus*).
The Musk-sheep (*Ovibos moschatus*).
The Tichorhine Rhinoceros (*R. tichorhinus*).
The Mammoth (*Elephas primigenius*).
The Lemming (*Myodes lemmus*).
The Cave Pika (*Lagomys*).
The Pouched Marmot (*Spermophilus*).
Spermophilus erythrogenoides.

Geographical Succession of Organic Forms.

A few words may be said here on a law which may be called the "law of the geographical succession of organic forms," and which is illustrated more completely by the *Mammalia* than by any other extinct animals. An examination, namely, of the facts of the geological distribution of Mammals, leads to the striking generalisation that "the present distribution of organic *forms* dates back to a period anterior to the origin of

existing *species*" (Lyell). In other words, though the extinct Mammals of the later geological deposits of any given country differ *specifically* from those now existing in the same country, they are nevertheless referable to the same *orders*, and are in every respect more closely allied to the present Mammalian fauna than to that of any other country. A few examples will render this perfectly clear.

Australia at the present day is an altogether peculiar zoological province, characterised by the abundance and variety of Marsupials which inhabit it. In the Post-tertiary deposits of Australia, however, we are presented with proofs that Marsupials were just as characteristic of Australia during late geological epochs as they are now. In the Post-pliocene period we know that Australia was occupied by Kangaroos, Kangaroo-rats, Wombats, Phalangers, and Carnivorous Marsupials, in every way *representing* the living Marsupials in zoological value, but *specifically* distinct, and generally of gigantic size.

In the same way, South America at the present day is especially characterised by a Mammalian fauna containing many peculiar forms, the *Edentata* being especially conspicuous, and having a larger representation than in any other region. Similar but distinct forms, however, are found to have existed in South America anterior to the creation of any existing species. Thus, the modern Sloths of South America are represented by the colossal *Mylodon, Megalonyx, Scelidotherium*, and *Megatherium*. The little armour-plated Armadillos are represented by the equally colossal *Glyptodon*. The Llamas—representing in South America the Camels of the Old World—are represented by the curious extinct genus *Macrauchenia*. The Platyrhine Monkeys have their extinct representatives. Fossil Tapirs take the place of the two existing species; and the Peccaries are represented by at least five extinct species of *Dicotyles*. The bone-caves of Brazil have also yielded remains of Sloths, Coatis, Kinkajous, Armadillos, Guinea-pigs, Agoutis, Capybaras, Pacas, Coypus, Vampire Bats, and *Cercolabes*, allied to, yet distinct from, the species now inhabiting South America.

Similarly, India is at present the only country in which four-horned Antelopes occur; and it is in the Siwalik Hills that there have been found the two gigantic four-horned Antelopes, which constitute the genera *Sivatherium* and *Bramatherium*.

In Europe, again, the Mammalian fauna of the later Tertiary periods is much more closely allied to that now characterising the Old World, than to that of the New. We have

the Lion, Bear, Wolf, Fox, and other well-known *Carnivora*. Elephants, Rhinoceroses, and Hippopotami, then as now, are characteristic Old World forms. The Ruminants are equally characteristic of the eastern hemisphere, though not exclusively confined to it, and they have numerous and varied representatives in later Tertiary deposits. The Giraffe is represented by the *Helladotherium*, and the Bactrian Camel by the *Merycotherium* of the Siberian Drift. The fossil *Quadrumana*, too, of Europe, all belong to the Catarhine section of the order.

It is unnecessary to pursue the subject further, but no law is more firmly established than this: "That with extinct as with existing Mammalia, particular forms were assigned to particular provinces; and that the same forms were restricted to the same provinces at a former geological period as they are at the present day" (Owen). It is to be borne in mind, however, that the law, as just stated, holds good for the later Tertiary period only, and does not apply, in any manner that admits of being traced, to the earlier geological epochs.

GLOSSARY.

ABDOMEN (Lat. *abdo*, I conceal). The posterior cavity of the body, containing the intestines and others of the viscera. In many Invertebrates there is no separation of the body-cavity into thorax and abdomen, and it is only in the higher *Annulosa* that a distinct abdomen can be said to exist.

ABERRANT (Lat. *aberro*, I wander away). Departing from the regular type.

ABNORMAL (Lat. *ab*, from; *norma*, a rule). Irregular; deviating from the ordinary standard.

ABRANCHIATE (Gr. *a*, without; *bragchia*, gill). Destitute of gills or branchiæ.

ACANTHOPTERYGII (Gr. *akantha*, spine; *pterux*, wing). A group of bony fishes with spinous rays in the front part of the dorsal fin.

ACARINA (Gr. *akari*, a mite). A division of the *Arachnida*, of which the Cheese-mite is the type.

ACEPHALOUS (Gr. *a*, without; *kephale*, head). Not possessing a distinct head.

ACETABULA (Lat. *acetabulum*, a cup). The suckers with which the cephalic processes of many *Cephalopoda* (Cuttle-fishes) are provided.

ACETABULUM. The cup-shaped socket of the hip-joint in Vertebrates.

ACRODONT (Gr. *akros*, high; *odous*, tooth). Applied to Lizards, in which the teeth are anchylosed with the summit of the jaw.

ACROGENS (Gr. *akros*, high; *gennao*, I produce.) Plants which increase in height by additions made to the summit of the stem, by the union of the bases of the leaves.

ACTINOZOA (Gr. *aktin*, a ray; and *zoön*, an animal). That division of the *Cœlenterata* of which the Sea-anemones may be taken as the type.

ALVEOLI (Lat. dim. of *alvus*, belly). Applied to the sockets of the teeth.

AMBULACRA (Lat. *ambulacrum*, a place for walking). The perforated spaces or "avenues" through which are protruded the tube-feet, by means of which locomotion is effected in the *Echinodermata*.

AMBULATORY (Lat. *ambulo*, I walk). Formed for walking. Applied to a single limb, or to an entire animal.

AMMONITIDÆ. A family of Tetrabranchiate Cephalopods, so called from the resemblance of the shell of the type-genus, *Ammonites*, to the horns of the Egyptian God, Jupiter-Ammon.

AMŒBA (Gr. *amoibos*, changing). A species of Rhizopod, so called from the numerous changes of form which it undergoes.

AMŒBIFORM. Resembling an *Amœba* in form.

AMORPHOZOA (Gr. *a*, without; *morphe*, shape; *zoön*, animal). A name sometimes used to designate the *Sponges*.

AMPHIBIA (Gr. *amphi*, both; *bios*, life). The Frogs, Newts, and the like, which have gills when young, but can always breathe air directly when adult.

AMPHICŒLOUS (Gr. *amphi*, at both ends; *koilos*, hollow). Applied to vertebræ which are concave at both ends.

AMPHIPODA (Gr. *amphi*, and *pous*, a foot). An order of *Crustacea*.

ANAL (Lat. *anus*, the vent). Connected with the anus, or situated near the anus.

ANARTHROPODA (Gr. *a*, without; *arthros*, a joint; *pous*, foot). That division of *Annulose* animals in which there are no articulated appendages.

ANCHYLOSIS or ANKYLOSIS (Gr. *ankulos*, crooked). The union of two bones by osseous matter, so that they become one bone, or are immovably joined together.

ANGIOSPERMS (Gr. *angeion*, a vessel; *sperma*, seed). Plants which have their seeds enclosed in a seed-vessel.

ANNELIDA (a Gallicised form of *Annulata*). The Ringed worms, which form one of the divisions of the *Anarthropoda*.

ANNULATED. Composed of a succession of rings.

ANNULOIDA (Lat. *annulus*, a ring; Gr. *eidos*, form). The sub-kingdom comprising the *Echinodermata* and the *Scolecida* (=*Echinozoa*).

ANNULOSA (Lat. *annulus*). The sub-kingdom comprising the *Anarthropoda* and the *Arthropoda* or *Articulata*, in all of which the body is more or less evidently composed of a succession of rings.

ANOMODONTIA (Gr. *anomos*, irregular; *odous*, tooth). An extinct order of Reptiles, often called *Dicynodontia*.

ANOMURA (Gr. *anomos*, irregular; *oura*, tail). A tribe of Decapod *Crustacea*, of which the Hermit-crab is the type.

ANOPLOTHERIDÆ (Gr. *anoplos*, unarmed; *ther*, beast). A family of Tertiary Ungulates.

ANOURA (Gr. *a*, without; *oura*, tail). The order of *Amphibia* comprising the Frogs and Toads, in which the adult is destitute of a tail. Often called *Batrachia*.

ANTENNÆ (Lat. *antenna*, a yard-arm). The jointed horns or feelers possessed by the majority of the *Articulata*.

ANTENNULES (dim. of *Antennæ*). Applied to the smaller pair of antennæ in the *Crustacea*.

ANTIBRACHIUM (Gr. *anti*, in front of; *brachion*, the arm). The fore-arm of the higher Vertebrates, composed of the *radius* and *ulna*.

ANTLERS. Properly the branches of the horns of the Deer tribe (*Cervidæ*), but generally applied to the entire horns.

APIOCRINIDÆ (Gr. *apion*, a pear; *krinon*, lily). A family of Crinoids—the "Pear-encrinites."

APLACENTALIA. The section of the *Mammalia*, comprising the two divisions of the *Didelphia* and *Monodelphia*, in which the young is not furnished with a placenta.

APODA (Gr. *a*, without; *podes*, feet). Applied to those fishes which have no ventral fins. Also to the footless *Cæciliæ* amongst the *Amphibia*.

APODAL. Devoid of feet.

APTERA (Gr. *a*, without; *pteron*, a wing). A division of Insects, which is characterised by the absence of wings in the adult condition.

APTEROUS. Devoid of wings.

APTERYX (Gr. *a*, without; *pterux*, a wing). A wingless bird of New Zealand, belonging to the order *Cursores*.

ARACHNIDA (Gr. *arachne*, a spider). A class of the *Articulata*, comprising Spiders, Scorpions, and allied animals.

ARBORESCENT. Branched like a tree.

ARCHÆOPTERYX (Gr. *archaios*, ancient; *pterux*, wing). The singular fossil bird which alone constitutes the order of the *Saururæ*.

ARENACEOUS. Sandy, or composed of grains of sand.

ARTICULATA (Lat. *articulus*, a joint). A division of the animal kingdom, comprising Insects, Centipedes, Spiders, and Crustaceans, characterised by the possession of jointed bodies or jointed limbs. The term *Arthropoda* is now more usually employed.

ARTIODACTYLA (Gr. *artios*, even; *daktulos*, a finger or toe). A division of the hoofed quadrupeds (*Ungulata*) in which each foot has an even number of toes (two or four).

ASCIDIOIDA (Gr. *askos*, a bottle; *eidos*, a form). A synonym of *Tunicata*, a class of Molluscous animals, which have the shape, in many cases, of a two-necked bottle.

ASEXUAL. Applied to modes of reproduction in which the sexes are not concerned.

ASIPHONATE. Not possessing a respiratory tube or siphon. (Applied to a division of the *Lamellibranchiate* Molluscs).

ASTEROID (Gr. *aster*, a star; and *eidos*, form). Star-shaped, or possessing radiating lobes or rays like a star-fish.

ASTEROIDEA. An order of *Echinodermata*, comprising the Star-fishes, characterised by their rayed form.

ASTOMATOUS (Gr. *a*, without; *stoma*, mouth). Not possessing a mouth.

ATLAS (Gr. the God who holds up the earth). The first vertebra of the neck, which articulates with and supports the skull.

AVES (Lat. *avis*, a bird). The class of the Birds.

AVICULARIUM (Lat. *avicula*, dim. of *avis*, a Bird). A singular appendage, often shaped like the head of a bird, found in many of the *Polyzoa*.

AXIS (Gr. *axon*, a pivot). The second vertebra of the neck, upon which the skull and atlas usually rotate.

AZYGOUS (Gr. *a*, without; *zugon*, yoke). Single; without a fellow.

BALANIDÆ (Gr. *balanos*, an acorn). A family of sessile *Cirripedes*, commonly called "Acorn-shells."

BALEEN (Lat. *balæna*, a whale). The horny plates which occupy the palate of the true or "whalebone" Whales.

BATIDES (Gr. *batos*, a bramble). The family of the *Elasmobranchii* comprising the Rays.

BATRACHIA (Gr. *batrachos*, a frog). Often loosely applied to any of the *Amphibia*, but sometimes restricted to the Amphibians as a class, or to the single order of the *Anoura*.

BELEMNITIDÆ (Gr. *belemnon*, a dart). An extinct group of Dibranchiate Cephalopods, comprising the Belemnites and their allies.

BIFID. Cleft into two parts; forked.

BILATERAL. Having two symmetrical sides.

BIMANA (Lat. *bis*, twice; *manus*, a hand). The order of *Mammalia* comprising man alone.

BIPEDAL (Lat. *bis*, twice; *pes*, foot). Walking upon two legs.

BIVALVE (Lat. *bis*, twice; *valvæ*, folding-doors). Composed of two plates or valves; applied to the shell of the *Lamellibranchiata* and *Brachiopoda*, and to the carapace of certain *Crustacea*.

BLASTOIDEA (Gr. *blastos*, a bud; and *eidos*, form). An extinct order of *Echinodermata*, often called *Pentremites*.

BRACHIOPODA (Gr. *brachion*, an arm; *pous*, the foot). A class of the *Molluscoida*, often called "Lamp-shells," characterised by possessing two fleshy arms continued from the sides of the mouth.

BRACHIUM (Gr. *brachion*, arm). Applied to the upper arm of Vertebrates.

BRACHYURA (Gr. *brachus*, short; *oura*, tail). A tribe of the Decapod *Crustaceans* with short tails (*i.e.*, the Crabs).

BRADYPODIDÆ (Gr. *bradus*, slow; *podes*, feet). The family of *Edentata* comprising the Sloths.

BRANCHIA (Gr. *bragchia*, the gill of a fish). A respiratory organ adapted to breathe air dissolved in water.

BRANCHIATE. Possessing gills or branchiæ.

BRANCHIFERA (Gr. *bragchia*, gill; and *phero*, I carry). A division of *Gasteropodous Molluscs*, in which the respiration is aquatic, and the respiratory organs are mostly in the form of distinct gills.

BRANCHIO-GASTEROPODA (= Branchifera).

BRANCHIOPODA (Gr. *bragchia*; and *pous*, foot). A legion of *Crustacea*, in which the gills are supported by the feet.

BRANCHIOSTEGAL (Gr. *bragchia*, gill; *stego*, I cover). Applied to a membrane and rays by which the gills are protected in many fishes.

Bruta (Lat. *brutus*, heavy, stupid). Often used to designate the Mammalian order of the *Edentata.*

Bryozoa (Gr. *bruon*, moss; *zoön*, animal). A synonym of *Polyzoa*, a class of the *Molluscoida.*

Buccal (Lat. *bucca*, mouth or cheeks). Connected with the mouth.

Bursiform (Lat. *bursa*, a purse; *forma*, shape). Shaped like a purse; subspherical.

Byssiferous. Producing a byssus.

Byssus (Gr. *bussos*, flax). A term applied to the silky filaments by which the *Pinna*, the common Mussel, and certain other bivalve *Mollusca*, attach themselves to foreign objects.

Caducibranchiate (Lat. *caducus*, falling off; Gr. *bragchia*, gill). Applied to those Amphibians in which the gills fall off before maturity is reached.

Caducous. Applied to parts which fall off or are shed during the life of the animal.

Cæcal (Lat. *cæcus*, blind). Terminating blindly, or in a closed extremity.

Cæcum (Lat. *cæcus*). A tube which terminates blindly.

Cæspitose (Lat. *cæspes*, a turf). Tufted.

Cainozoic. (*See* Kainozoic.)

Calamites (Lat. *calamus*, a reed). Extinct plants with reed-like stems, believed to be gigantic representatives of the *Equisetaceæ.*

Calcareous (Lat. *calx*, lime). Composed of carbonate of lime.

Calice. The little cup in which the polype of a coralligenous Zoophyte (*Actinozoön*) is contained.

Calycophoridæ (Gr. *kalux*, a cup; and *phero*, I carry). An order of the Oceanic *Hydrozoa*, so called from their possessing bell-shaped swimming organs (*nectocalyces*).

Calyx (Lat. *calyx*, a cup). Applied to the cup-shaped body of *Vorticella* (*Protozoa*), or of a *Crinoid* (*Echinodermata*).

Campanularida (Lat. *campanula*, a bell). An order of Hydroid Zoophytes.

Canine (Lat. *canis*, a dog). The eye-tooth of Mammals, or the tooth which is placed at or close to the præmaxillary suture in the upper jaw, and the corresponding tooth in the lower jaw.

Capitulum (Lat. dim. of *caput*, head). Applied to the body of a Barnacle (*Lepadidæ*), from its being supported upon a stalk or peduncle.

Carapace. A protective shield. Applied to the upper shell of Crabs, Lobsters, and many other *Crustacea;* also to the case with which certain of the *Infusoria* are provided. Also the upper half of the immovable case in which the body of a Chelonian is protected.

Carinatæ (Lat. *carina*, a keel). Applied by Huxley to all those birds in which the sternum is furnished with a median ridge or keel.

Carnivora (Lat. *caro*, flesh; *voro*, I devour). An order of the *Mammalia.*

Carnivorous (Lat. *caro*, flesh; *voro*, I devour). Feeding upon flesh.

Carnose (Lat. *caro*). Fleshy.

Carpus (Gr. *karpos*, the wrist). The small bones which intervene between the fore-arm and the metacarpus.

Catarhina (Gr. *kata*, downwards; *rhines*, nostrils). A group of the *Quadrumana.*

Caudal (Lat. *cauda*, the tail). Belonging to the tail.

Cavicornia (Lat. *cavus*, hollow; *cornu*, a horn). The "hollow-horned" Ruminants, in which the horn consists of a central bony "horn-core" surrounded by a horny sheath.

Centrum (Gr. *kentron*, the point round which a circle is described by a pair of compasses). The central portion or "body" of a vertebra.

Cephalaspidæ (Gr. *kephale*, head; *aspis*, shield). A family of fossil fishes.

Cephalic (Gr. *kephale*, head). Belonging to the head.

Cephalo-branchiate (Gr. *kephale;* and *bragchia*, gill). Carrying gills upon the head. Applied to a section of the *Annelida*, which, like the *Serpulæ*, have tufts of external gills placed upon the head.

CEPHALOPHORA (Gr. *kephale;* and *phero,* I carry). Used synonymously with *Encephala,* to designate those *Mollusca* which possess a distinct head.

CEPHALOPODA (Gr. *kephale;* and *podes,* feet). A class of the *Mollusca,* comprising the Cuttle-fishes and their allies, in which there is a series of arms ranged round the head.

CEPHALOTHORAX (Gr. *kephale;* and *thorax,* chest). The anterior division of the body in many *Crustacea* and *Arachnida,* which is composed of the coalesced head and chest.

CERVICAL (Lat. *cervix,* neck). Connected with the region of the neck.

CESTRAPHORI (Gr. *kestra,* a weapon; *phero,* I carry). The group of *Elasmobranchii* represented at the present day by the Port Jackson Shark.

CETACEA (Gr. *kētos,* a whale). The order of Mammals comprising the Whales and Dolphins.

CHEIROPTERA (Gr. *cheir,* hand; *pteron,* a wing). The order of Mammals comprising the Bats.

CHELÆ (Gr. *chele,* a claw). The prehensile claws with which some of the limbs are terminated in certain *Crustacea,* such as the Crab, Lobster, &c.

CHELATE. Possessing chelæ; applied to a limb.

CHELICERÆ (Gr. *chele,* a claw; and *keras,* a horn). The prehensile claws of the Scorpion, supposed to be homologous with antennæ.

CHELONIA (Gr. *chelone,* a tortoise). The order of Reptiles comprising the Tortoises and Turtles.

CHELONOBATRACHIA (Gr. *chelone,* a tortoise; *batrachos,* a frog). Sometimes applied to the Amphibian order of the *Anoura* (Frogs and Toads).

CHILOGNATHA (Gr. *cheilos,* a lip; and *gnathos,* a jaw). An order of the *Myriapoda.*

CHILOPODA (Gr. *cheilos;* and *podes,* feet). An order of the *Myriapoda.*

CHITINE (Gr. *chiton,* a coat). The peculiar chemical principle, nearly allied to horn, which forms the exoskeleton in many Invertebrate Animals, especially in the *Arthropoda* (*Crustacea, Insecta,* &c.)

CIRRI (Lat. *cirrus,* a curl). Tendril-like appendages, such as the feet of Barnacles and Acorn-shells (*Cirripedes*), the lateral processes on the arms of *Brachiopoda,* &c.

CIRRIFEROUS or CIRRIGEROUS. Carrying cirri.

CIRRIPEDIA, CIRRHIPEDIA, or CIRRHOPODA (Lat. *cirrus,* a curl; and *pes,* a foot). A sub-class of *Crustacea* with curled jointed feet.

CLADOCERA (Gr. *klados,* a branch; *keras,* a horn). An order of *Crustacea* with branched antennæ.

CLAVATE (Lat. *clavus,* a club). Club-shaped.

CLAVICLE (Lat. *clavicula,* a little key). The "collar-bone," forming one of the elements of the pectoral arch of Vertebrates.

CLOACA (Lat. a sink). The cavity into which the intestinal canal and the ducts of the generative and urinary organs open in common, in some Invertebrates (*e.g.,* in Insects), and also in many Vertebrate animals.

CLYPEIFORM (Lat. *clypeus,* a shield; and *forma,* shape). Shield-shaped; applied, for example, to the carapace of the King-crab.

CŒLENTERATA (Gr. *koilos,* hollow; *enteron,* the bowel). The sub-kingdom which comprises the *Hydrozoa* and *Actinozoa.* Proposed by Frey and Leuckhart in place of the old term *Radiata,* which included other animals as well.

CŒNENCHYMA (Gr. *koinos,* common; *enchuma,* tissue, literally an infusion). The common calcareous tissue which unites together the various corallites of a compound corallum.

CŒNŒCIUM (Gr. *koinos,* common; *oikos,* house). The entire dermal system of any *Polyzoön:* employed in place of the terms polyzoary or polypidom.

CŒNOSARC (Gr. *koinos,* common; *sarx,* flesh). The common organised medium by which the separate polypites of a compound *Hydrozoön* are connected together.

COLEOPTERA (Gr. *koleos,* a sheath; *pteron,* wing). The order of Insects (Beetles) in which the anterior pair of wings are hardened, and serve as protective cases for the posterior pair of membranous wings.

COLUBRINA (Lat. *coluber*, a snake). A division of the *Ophidia*.
COLUMBACEI (Lat. *columba*, a dove). The division of Rasorial birds comprising the Doves and Pigeons.
COLUMELLA (Lat. dim. of *columna*, a column). In Conchology, the central axis round which the whorls of a spiral univalve are wound. Amongst the *Actinozoa*, it is the central axis or pillar which is found in the centre of the thecæ of many corals.
COLUMN. Applied to the cylindrical body of a Sea-anemone (*Actinia*); also to the jointed stem or peduncle of the stalked *Crinoids*..
CONCHIFERA (Lat *concha*, a shell; *fero*, I carry). Shell-fish. Applied in a restricted sense to the bivalve Molluscs, and used as a synonym for *Lamellibranchiata*.
CONDYLE (Gr. *kondulos*, a knuckle). The surface by which one bone articulates with another. Applied especially to the articular surface or surfaces by which the skull articulates with the vertebral column.
CONIROSTRES (Lat. *conus*, a cone; *rostrum*, a beak). The division of Perching Birds with conical beaks.
COPEPODA (Gr. *kope*, an oar; *podes*, feet). An order of *Crustacea*.
CORACOID (Gr. *korax*, a crow; *eidos*, form). One of the bones which enters into the composition of the pectoral arch in Birds, Reptiles, and Monotremes. In most Mammals it is a mere process of the scapula, having, in man, some resemblance in shape to the beak of a crow.
CORALLIGENOUS. Producing a corallum.
CORALLITE. The corallum secreted by an *Actinozoön* which consists of a single polype; or the portion of a composite corallum which belongs to, and is secreted by, an individual polype.
CORALLUM (from the Latin for Red Coral). The hard structures deposited in, or by, the tissues of an *Actinozoön*—commonly called a "coral."
CORIACEOUS (Lat. *corium*, hide). Leathery.
CORYNIDA (Gr. *korune*, a club). A group of the Hydroid Zoophytes, so called from their sometimes possessing clubbed tentacles.
COSTÆ (Lat. *costa*, a rib). Applied amongst the *Crinoidea* to designate the rows of plates which succeed the inferior or basal portion of the cup (pelvis). Amongst the *Corals* the "costæ" are vertical ridges which occur on the outer surface of the theca, and mark the position of the septa within.
COSTAL (Lat. *costa*, a rib). Connected with the ribs.
CRANIUM (Gr. *kranion*, the skull). The bony or cartilaginous case in which the brain is contained.
CRINOIDEA (Gr. *krinon*, a lily; *eidos*, form). An order of *Echinodermata*, comprising forms which are usually stalked, and sometimes resemble lilies in shape.
CROCODILIA (Gr. *krokodeilos*, a crocodile). An order of Reptiles.
CROSSOPTERYGIDÆ (Gr. *krossotos*, a fringe; *pterux*, a fin). A sub-order of Ganoids in which the paired fins possess a central lobe.
CRUSTACEA (Lat. *crusta*, a crust). A class of Articulate animals, comprising Crabs, Lobsters, &c., characterised by the possession of a hard shell or crust, which they cast periodically.
CRYPTOGAMS (Gr. *kruptos*, concealed; *gamos*, marriage). A division of plants in which the organs of reproduction are obscure and there are no true flowers.
CTENOID (Gr. *kteis*, a comb; *eidos*, form). Applied to those scales of fishes, the hinder margins of which are fringed with spines or comb-like projections.
CTENOPHORA (Gr. *kteis*, a comb; and *phero*, I carry). An order of *Actinozoa*, comprising oceanic creatures, which swim by means of "ctenophores," or bands of cilia arranged in comb-like plates.
CURSORES (Lat. *curro*, I run). An order of *Aves*, comprising birds destitute of the power of flight, but formed for running vigorously (*e.g.*, the Ostrich and Emeu).
CUSPIDATE. Furnished with small pointed eminences or "cusps."
CUTICLE (Lat. *cuticula*, dim. of *cutis*, skin). The pellicle which forms the

outer layer of the body amongst the *Infusoria*. The outer layer of the integument generally.

CYCLOID (Gr. *kuklos*, a circle; *eidos*, form). Applied to those scales of fishes which have a regularly circular or elliptical outline with an even margin.

CYCLOSTOMI (Gr. *kuklos*, and *stoma*, mouth). Sometimes used to designate the Hag-fishes and Lampreys, forming the order *Marsipobranchii*.

CYST (Gr. *kustis*, a bladder or bag). A sac or vesicle.

CYSTOIDEA (Gr. *kustis*, a bladder; and *eidos*, form). An extinct order of *Echinodermata*.

DECAPODA (Gr. *deka*, ten; *podes*, feet). The division of *Crustacea* which have ten ambulatory feet; also the family of Cuttle-fishes, in which there are ten arms or cephalic processes.

DECIDUOUS (Lat. *decido*, I fall off). Applied to parts which fall off or are shed during the life of the animal.

DECOLLATED (Lat. *decollo*, I behead). Applied to univalve shells, the apex of which falls off in the course of growth.

DEINOSAURIA (Gr. *deinos*, terrible; *saura*, lizard). An extinct order of Reptiles.

DENDRIFORM, DENDRITIC, DENDROID (Gr. *dendron*, a tree). Branched like a tree, arborescent.

DERMAL (Gr. *derma*, skin). Belonging to the integument.

DESMIDIÆ. Minute fresh-water plants, of a green colour, without a siliceous epidermis.

DEXTRAL (Lat. *dextra*, the right hand). Right-handed. Applied to the direction of the spiral in the greater number of univalve shells.

DIAPHRAGM (Gr. *diaphragma*, a partition). The "midriff" or the muscle which in *Mammalia* forms a partition between the cavities of the thorax and abdomen.

DIASTEMA (Gr. *dia*, apart; *histemi*, to place). A gap or interval, especially between teeth.

DIATOMACEÆ (Gr. *diatemno*, I sever). An order of minute plants, which are provided with siliceous envelopes.

DIBRANCHIATA (Gr. *dis*, twice; *bragchia*, gill). The order of *Cephalopoda* (comprising the Cuttle-fishes, &c.) in which only two gills are present.

DICYNODONTIA (Gr. *dis*, twice; *kuon*, dog; *odous*, tooth). An extinct order of Reptiles.

DIDELPHIA (Gr. *dis*, twice; *delphus*, womb). The subdivision of Mammals comprising the Marsupials.

DIGIT (Lat. *digitus*, a finger). A finger or toe.

DIGITIGRADA (Lat. *digitus*; *gradior*, I walk). A subdivision of the *Carnivora*.

DIGITIGRADE. Walking upon the tips of the toes, and not upon the soles of the feet.

DIMYARY (Gr. *dis*, twice; *muon*, muscle). Applied to those bivalve Molluscs (*Lamellibranchiata*) in which the shell is closed by two adductor muscles.

DIPHYODONT (Gr. *dis*, twice; *phuo*, I generate; *odous*, tooth). Applied to those Mammals which have two sets of teeth.

DIPNOI (Gr. *dis*, twice; *pnoe*, breath). The order of Fishes represented by the *Lepidosiren*.

DIPTERA (Gr. *dis*, twice; *pteron*, wing). An order of Insects characterised by the possession of two wings.

DISCOID (Gr. *diskos*, a quoit; *eidos*, form). Shaped like a round plate or quoit.

DISCOPHORA (Gr. *diskos*, a quoit; *phero*, I carry). This term is applied to the *Medusæ*, or Jelly-fishes, from their form; and is sometimes used to designate the order of the Leeches (*Hirudinea*), from the suctorial discs which these animals possess.

DISSEPIMENTS (Lat. *dissepio*, I partition off). Partitions. Used in a restricted sense to designate certain imperfect transverse partitions, which grow from the septa of many corals.

DISTAL. Applied to the quickly-growing end of the hydrosoma of a *Hydro-*

zoön; the opposite, or "proximal," extremity growing less rapidly, and being the end by which the organism is fixed, when attached at all.

DIURNAL (Lat. *dies*, day). Applied to animals which are active during the day.

DORSAL (Lat. *dorsum*, back). Connected with the back.

DORSIBRANCHIATE (Lat. *dorsum*, the back; Gr. *bragchia*, gill). Having external gills attached to the back; applied to certain *Annelides* and *Molluscs*. The term is of mongrel composition, and "notobranchiate" is more correctly employed.

ECHINODERMATA (Gr. *echinos;* and *derma*, skin). A class of animals comprising the Sea-urchins, Star-fishes, and others, most of which have spiny skins.

ECHINOIDEA (Gr. *echinos;* and *eidos*, form). An order of *Echinodermata*, comprising the Sea-urchins.

ECHINULATE. Possessing spines.

ECTOCYST (Gr. *ektos*, outside; *kustis*, a bladder). The external investment of the cœnœcium of a *Polyzoön*.

ECTODERM (Gr. *ektos*, and *derma*, skin). The external integumentary layer of the *Cœlenterata*.

EDENTATA (Lat. *e*, without; *dens*, tooth). An order of *Mammalia* often called *Bruta*.

EDENTULOUS. Toothless, without any dental apparatus. Applied to the mouth of any animal, or to the hinge of the bivalve Molluscs.

EDRIOPHTHALMATA (Gr. *hedraios*, sitting; *ophthalmos*, eye). The division of *Crustacea* in which the eyes are sessile, and are not supported upon stalks.

ELASMOBRANCHII (Gr. *elasma*, a plate; *bragchia*, gill). An order of Fishes, including the Sharks and Rays.

ELYTRA (Gr. *elutron*, a sheath). The chitinous anterior pair of wings in Beetles, which form cases for the posterior membranous wings. Also applied to the scales or plates on the back of the Sea-mouse (*Aphrodite*).

EMBRYO (Gr. *en*, in; *bruo*, I swell). The earliest stage at which the young animal is recognisable in the impregnated ovum.

ENALIOSAURIA (Gr. *enalios*, marine; *saura*, lizard). Sometimes employed as a common term to designate the extinct Reptilian orders of the *Ichthyosauria* and *Plesiosauria*.

ENCEPHALOUS (Gr. *en*, in; *kephale*, the head). Possessing a distinct head. Usually applied to all the *Mollusca* proper, except the *Lamellibranchiata*.

ENDOCYST (Gr. *endon*, within; *kustis*, a bag). The inner membrane or integumentary layer of a *Polyzoön*. In *Cristatella*, where there is no "ectocyst," the endocyst constitutes the entire integument.

ENDODERM (Gr. *endon;* and *derma*, skin). The inner integumentary layer of the *Cœlenterata*.

ENDOPODITE (Gr. *endon;* and *pous*, foot). The inner of the two secondary joints into which the typical limb of a *Crustacean* is divided.

ENDOSKELETON (Gr. *endon;* and *skeletos*, dry). The internal hard structures, such as bones, which serve for the attachment of muscles, or the protection of organs, and which are not a mere hardening of the integument.

ENSIFORM (Lat. *ensis*, a sword; *forma*, shape). Sword-shaped.

ENTOMOPHAGA (Gr. *entoma*, insects; *phago*, I eat). A section of the Marsupialia.

ENTOMOSTRACA (Gr. *entoma*, insects; *ostrakon*, a shell). Literally Shelled Insects, applied to a division of *Crustacea*.

ENTOZOA (Gr. *entos*, within; *zoön*, animal). Animals which are parasitic in the interior of other animals.

EOCENE (Gr. *eos*, dawn; *kainos*, new or recent). The lowest division of the Tertiary Rocks, in which species of existing shells are to a small extent represented.

EPIDERMIS (Gr. *epi*, upon; *derma*, the true skin). The outer non-vascular layer of the skin, often called the scarf-skin or *cuticle*.

EPIMERA (Gr. *epi*, upon; *mēron*, thigh). The lateral pieces of the dorsal arc of the somite of a *Crustacean*.

EPIPODIA (Gr. *epi*, upon; *pous*, the foot). Muscular lobes developed from the lateral and upper surfaces of the "foot" of some *Molluscs*.

EPIPODITE (Gr. *epi*, upon; *pous*, foot). A process developed upon the basal joint, or "protopodite," of some of the limbs of certain *Crustacea*.

EPISTERNA (Gr. *epi*, upon; *sternon*, the breast-bone). The lateral pieces of the inferior or ventral arc of the somite of a *Crustacean*.

EPISTOME (Gr. *epi*; and *stoma*, mouth). A valve-like organ which arches over the mouth in certain of the *Polyzoa*.

EPITHECA (Gr. *epi*; and *theke*, a sheath). A continuous layer surrounding the thecæ in some Corals externally.

EPIZOA (Gr. *epi*, upon; *zoön*, animal). Animals which are parasitic upon other animals. In a restricted sense, a division of *Crustacea* which are parasitic upon fishes.

EQUILATERAL (Lat. *æquus*, equal; *latus*, side). Having its sides equal. Usually applied to the shells of the *Brachiopoda*. When applied to the spiral shells of the *Foraminifera*, it means that all the convolutions of the shell lie in the same plane.

EQUISETACEA (Lat. *equus*, horse; *seta*, bristle). A group of Cryptogamous plants, commonly known as "Horse-tails."

EQUIVALVE (Lat. *æquus*, equal; *valvæ*, folding-doors). Applied to shells which are composed of two equal pieces or valves.

ERRANTIA (Lat. *erro*, I wander). An order of *Annelida*, often called *Nereidea*, distinguished by their great locomotive powers.

EURYPTERIDA (Gr. *eurus*, broad; *pteron*, wing). An extinct sub-order of *Crustacea*.

EXOPODITE (Gr. *exo*, outside; *pous*, foot). The outer of the two secondary joints into which the typical limb of a *Crustacean* is divided.

EXOSKELETON (Gr. *exo*, outside; *skeletos*, dry. The external skeleton, which is constituted by a hardening of the integument, and is often called a "dermoskeleton."

FASCICULATED (Lat. *fasciculus*, a bundle). Arranged in bundles.

FAUNA (Lat. *Fauni*, the rural deities of the Romans). The general assemblage of the animals of any region or district.

FEMUR. The thigh-bone, intervening between the pelvis and the bones of the leg proper (*tibia* and *fibula*).

FIBULA (Lat. a brooch). The outermost of the two bones of the leg in the higher *Vertebrata*; corresponding to the *ulna* of the fore-arm.

FILICES (Lat. *filix*, a fern). The order of Cryptogamic plants comprising the Ferns.

FILIFORM (Lat. *filum*, a thread; *forma*, shape). Thread-shaped.

FISSION (Lat. *findo*, I cleave). Multiplication by means of a process of self-division.

FISSIPAROUS (Lat. *findo*; and *pario*, I produce). Giving origin to fresh structures by a process of fission.

FLORA (Lat. *Flora*, the goddess of flowers). The general assemblage of the plants of any region or district.

FOOT-JAWS. The limbs of *Crustacea*, which are modified to subserve mastication.

FOOT-SECRETION. The term applied by Mr Dana to the sclerobasic corallum of certain *Actinozoa*.

FOOT-TUBERCLES. The unarticulated appendages of the *Annelida*, often called parapodia.

FORAMINIFERA (Lat. *foramen*, an aperture; *fero*, I carry). An order of *Protozoa*, usually characterised by the possession of a shell perforated by numerous pseudopodial apertures.

FRUGIVOROUS (Lat. *frux*, fruit; *voro*, I devour). Living upon fruits.

FUCOIDS (Lat. *fucus*, sea-weed; Gr. *eidos*, likeness). Fossils, often of an obscure nature, believed to be the remains of sea-weeds.

FURCULUM or FURCULA (Lat. dim. of *furca*, a fork). The "merry-thought" of birds, or the V-shaped bone formed by the united clavicles.

FUSIFORM (Lat. *fusus*, a spindle; and *forma*, shape). Spindle-shaped, or pointed at both ends.

GALLINACEI (Lat. *gallina*, a fowl). Sometimes applied to the whole order of the Rasorial Birds, but properly restricted to that section of the order of which the common Fowl is a typical example.

GANGLION (Gr. *gagglion*, a knot). A mass of nervous matter containing nerve-cells, and giving origin to nerve-fibres.

GANOID (Gr. *ganos*, splendour, brightness). Applied to those scales or plates which are composed of an inferior layer of true bone covered by a superior layer of polished enamel.

GANOIDEI. An order of Fishes.

GASTEROPODA (Gr. *gaster*, stomach; *pous*, foot). The class of the *Mollusca* comprising the ordinary univalves, in which locomotion is usually effected by a muscular expansion of the under surface of the body (the "foot").

GEMMÆ (*gemma*, a bud). The buds produced by any animal, whether detached or not.

GEMMATION. The process of producing new structures by budding.

GEMMIPAROUS (Lat. *gemma*, a bud; *pario*, I produce). Giving origin to new structures by a process of budding.

GEPHYREA (Gr. *gephura*, a bridge). A class of the *Anarthropoda*, comprising the Spoon-worms (*Sipunculus*) and their allies.

GIZZARD. A muscular division of the stomach in Birds, Insects, &c.

GLADIUS (Lat. a sword). Applied to the horny endoskeleton or "pen" of certain Cuttle-fishes.

GLENOID (Gr. *glene*, a cavity; *eidos*, form). A shallow cavity; applied especially to the shallow articular cavity in the shoulder-blade to which the head of the humerus is jointed.

GRALLATORES (Lat. *grallæ*, stilts). The order of the long-legged Wading Birds.

GRAPTOLITIDÆ (Gr. *grapho*, I write; *lithos*, stone). An extinct sub-class of the *Hydrozoa*.

GREGARINIDA (Lat. *gregarius*, occurring in numbers together). A class of the *Protozoa*.

GUARD. The cylindrical fibrous sheath with which the internal chambered shell (phragmacone) of a *Belemnite* is protected.

GYMNOLÆMATA (Gr. *gumnos*, naked; *laimos*, the throat). An order of the *Polyzoa* in which the mouth is devoid of the valvular structure known as the "epistome."

GYMNOPHIONA (Gr. *gumnos*, naked; *ophis*, a snake). The order of the *Amphibia* comprising the snake-like *Cæciliæ*.

GYMNOPHTHALMATA (Gr. *gumnos*; and *ophthalmos*, the eye). Applied by Edward Forbes to those *Medusæ* in which the eye-specks at the margin of the disc are unprotected. The division is now abandoned.

GYMNOSOMATA (Gr. *gumnos*; and *soma*, the body). The order of *Pteropoda* in which the body is not protected by a shell.

HALLUX (Lat. *allex*, the thumb or great toe). The innermost of the five digits which normally compose the *hind* foot of a Vertebrate animal. In man, the great toe.

HEMIPTERA (Gr. *hemi*; and *pteron*, wing). An order of Insects in which the anterior wings are sometimes "hemelytra."

HERMAPHRODITE (Gr. *Hermes*, Mercury; *Aphrodite*, Venus). Possessing the characters of both sexes combined.

HETEROCERCAL (Gr. *heteros*, diverse; *kerkos*, tail.) Applied to the tail of Fishes when it is unsymmetrical, or composed of two unequal lobes.

HETEROPODA (Gr. *heteros*, diverse; *podes*, feet). An aberrant group of the Gasteropods, in which the foot is modified so as to form a swimming organ.

HIRUDINEA (Lat. *hirudo*, a horse-leech). The order of *Annelida* comprising the Leeches.

HISTOLOGY (Gr. *histos*, a web; *logos*, a discourse). The study of the tissues, more especially of the minuter elements of the body.

HOLOCEPHALI (Gr. *holos*, whole; *kephale*, head). A sub-order of the *Elasmobranchii* comprising the *Chimæræ*.

HOLOSTOMATA (Gr. *holos*, whole; *stoma*, mouth). A division of *Gasteropodous Molluscs*, in which the aperture of the shell is rounded, or "entire."

HOLOTHUROIDEA (Gr. *holothourion;* and *eidos*, form). An order of *Echinodermata* comprising the Trepangs.

HOMOCERCAL (Gr. *homos*, same; *kerkos*, tail). Applied to the tail of Fishes when it is symmetrical, or composed of two equal lobes.

HOMOLOGOUS (Gr. *homos;* and *logos*, a discourse). Applied to parts which are constructed upon the same fundamental plan.

HUMERUS. The bone of the upper arm (*brachium*) in the Vertebrates.

HYALINE (Gr. *hualos*, crystal). Crystalline or glassy.

HYBODONTS (Gr. *hubos*, curved; *odous*, tooth). A group of Fishes of which *Hybodus* is the type-genus.

HYDROIDA (Gr. *hudra;* and *eidos*, form). The sub-class of the *Hydrozoa*, which comprises the animals most nearly allied to the *Hydra*.

HYDROTHECA (Gr. *hudra;* and *theke*, a case). The little chitinous cups in which the polypites of the *Sertularida* and *Campanularida* are protected.

HYDROZOA (Gr. *hudra;* and *zoön*, animal). The class of the *Cœlenterata* which comprises animals constructed after the type of the *Hydra*.

HYMENOPTERA (Gr. *humen*, a membrane; *pteron*, a wing). An order of Insects (comprising Bees, Ants, &c.) characterised by the possession of four membranous wings.

HYOID (Gr. *U;* *eidos*, form). The bone which supports the tongue in Vertebrates, and derives its name from its resemblance in man to the Greek letter U.

HYPOSTOME (Gr. *hupo*, under; *stoma*, mouth). The upper lip, or "labrum," of certain *Crustacea* (*e.g.*, Trilobites).

HYRACOIDEA (Gr. *hurax*, a shrew; *eidos*, form). An order of the *Mammalia* constituted for the reception of the single genus *Hyrax*.

ICHTHYODORULITE (Gr. *ichthus*, fish; *dorus*, spear; *lithos*, stone). The fossil fin-spines of Fishes.

ICHTHYOMORPHA (Gr. *ichthus;* *morphe*, shape). An order of Amphibians, often called *Urodela*, comprising the fish-like Newts, &c.

ICHTHYOPHTHIRA (Gr. *ichthus;* *phtheir*, a louse). An order of *Crustacea* comprising animals which are parasitic upon Fishes.

ICHTHYOPSIDA (Gr. *ichthus;* *opsis*, appearance). The primary division of *Vertebrata*, comprising the Fishes and Amphibia. Often spoken of as the *Branchiate Vertebrata*.

ICHTHYOPTERYGIA (Gr. *ichthus;* *pterux*, wing). An extinct order of Reptiles.

ICHTHYOSAURIA (Gr. *ichthus;* *saura*, lizard). Synonymous with *Ichthyopterygia*.

ILIUM. The haunch-bone, one of the bones of the pelvic arch in the higher Vertebrates.

IMAGO (Lat. an image or apparition). The perfect insect, after it has undergone its metamorphoses.

IMBRICATED. Applied to scales or plates which overlap one another like tiles.

INCISOR (Lat. *incido*, I cut). The cutting teeth fixed in the intermaxillary bones of the *Mammalia*, and the corresponding teeth in the lower jaw.

INEQUILATERAL. Having the two sides unequal, as in the case of the shells of the ordinary bivalves (*Lamellibranchiata*). When applied to the shells of the *Foraminifera*, it implies that the convolutions of the shell do not lie in the same plane, but are obliquely wound round an axis.

INEQUIVALVE. Composed of two unequal pieces or valves.

INFUNDIBULUM (Lat. for funnel). The tube formed by the coalescence or apposition of the epipodia in the *Cephalopoda*. Commonly termed the "funnel," or "siphon."

INFUSORIA (Lat. *infusum*, an infusion). A class of *Protozoa*, so called because they are often developed in organic infusions.

INOPERCULATA (Lat. *in*, without; *operculum*, a lid). The division of pulmonate *Gasteropoda* in which there is no shelly or horny plate (operculum) by which the shell is closed when the animal is withdrawn within it.

INSECTA (Lat. *inseco*, I cut into). The class of articulate animals commonly known as Insects.

INSECTIVORA (Lat. *insectum*, an insect; *voro*, I devour). An order of Mammals.

INSECTIVOROUS. Living upon Insects.

INSESSORES (Lat. *insedeo*, I sit upon). The order of the Perching Birds, often called *Passeres*.

INTERAMBULACRA. The rows of plates in an *Echinoderm* which are not perforated for the emission of the "tube-feet."

INTERMAXILLÆ, or PRÆMAXILLÆ. The two bones which are situated between the two superior maxillæ in *Vertebrata*. In man, and some monkeys, the præmaxillæ anchylose with the maxillæ, so as to be irrecognisable in the adult.

INVERTEBRATA (Lat. *in*, without; *vertebra*, a bone of the back). Animals without a spinal column or backbone.

ISCHIUM (Gr. *ischion*, the hip). One of the bones of the pelvic arch in Vertebrates.

ISOPODA (Gr. *isos*, equal; *podes*, feet). An order of *Crustacea* in which the feet are like one another and equal.

JUGULAR (Lat. *jugulum*, the throat). Connected with, or placed upon, the throat. Applied to the ventral fins of fishes when they are placed beneath or in advance of the pectorals.

KAINOZOIC (Gr. *kainos*, recent; *zoe*, life). The Tertiary period in Geology, comprising those formations in which the organic remains approximate more or less closely to the existing fauna and flora.

KERATODE (Gr. *keras*, horn; *eidos*, form). The horny substance of which the skeleton of many sponges is made up.

KERATOSA. The division of Sponges in which the skeleton is composed of keratode.

LABIUM (Lat. for lip). Restricted to the lower lip of Articulate animals.

LABRUM (Lat. for lip). Restricted to the upper lip of Articulate animals.

LABYRINTHODONTIA (Gr. *laburinthos*, a labyrinth; *odous*, tooth). An extinct order of *Amphibia*, so called from the complex microscopic structure of the teeth.

LACERTILIA (Lat. *lacerta*, a lizard). An order of *Reptilia* comprising the Lizards and Slow-worms.

LÆMODIPODA (Gr. *laimos*, throat; *dis*, twice; *podes*, feet). An order of *Crustacea*, so called because they have two feet placed far forwards, as it were, under the throat.

LAMELLIBRANCHIATA (Lat. *lamella*, a plate; Gr. *bragchia*, gill). The class of *Mollusca*, comprising the ordinary bivalves, characterised by the possession of lamellar gills.

LAMELLIROSTRES (Lat. *lamella*, a plate; *rostrum*, beak). The flat-billed Swimming Birds (*Natatores*), such as Ducks, Geese, Swans, &c.

LARVA (Lat. a mask). The insect in its first stage after its emergence from the egg, when it is usually very different from the adult.

LARYNX. The upper part of the windpipe, forming a cavity with appropriate muscles and cartilages, situated beneath the hyoid bone, and concerned in Mammals in the production of vocal sounds.

LENTICULAR (Lat. *lens*, a bean). Shaped like a biconvex lens.

LEPIDODENDRON (Gr. *lepis*, a scale; *dendron*, a tree). A genus of extinct plants, so named from the scale-like scars upon the stem left by the falling off of the leaves.

LEPIDOPTERA (Gr. *lepis*, a scale ; *pteron*, a wing). An order of Insects, comprising Butterflies and Moths, characterised by possessing four wings which are usually covered with minute scales.

LEPIDOTA (Gr. *lepis*, a scale). Formerly applied to the order *Dipnoi*, containing the Mud-fishes (*Lepidosiren*).

LEPTOCARDIA (Gr. *leptos*, slender, small ; *cardia*, heart). The name given by Müller to the order of Fishes comprising the Lancelet, now called *Pharyngobranchii.*

LOPHOPHORE (Gr. *lophos*, a crest ; and *phero*, I carry). The disc or stage upon which the tentacles of the *Polyzoa* are borne.

LOPHYROPODA (Gr. *lophouros*, having stiff hairs ; and *podes*, feet). A section of *Crustacea*.

LORICATA (Lat. *lorica*, a cuirass). The division of Reptiles comprising the *Chelonia* and *Crocodilia*, in which bony plates are developed in the skin (*derma*).

LUCERNARIDA (Lat. *lucerna*, a lamp). An order of the *Hydrozoa*.

LUMBAR (Lat. *lumbus*, loin). Connected with the loins.

LUNATE (Lat. *luna*, moon). Crescentic in shape.

LYCOPODIACEÆ (Gr. *lupos*, a wolf ; *pous*, foot). The group of Cryptogamic plants generally known as "Club-mosses."

MACRURA (Gr. *makros*, long ; *oura*, tail). A tribe of Decapod *Crustaceans* with long tails (*e.g.*, the Lobster, Shrimp, &c.)

MADREPORIFORM. Perforated with small holes, like a coral ; applied to the tubercle by which the ambulacral system of the *Echinoderms* mostly communicates with the exterior.

MALACOSTRACA (Gr. *malakos*, soft ; *ostrakon*, shell). A division of *Crustacea*. Originally applied by Aristotle to the entire class *Crustacea*, because their shells were softer than those of the *Mollusca*.

MAMMALIA (Lat. *mamma*, the breast). The class of Vertebrate animals which suckle their young.

MANDIBLE (Lat. *mandibulum*, a jaw). The upper pair of jaws in Insects ; also applied to one of the pairs of jaws in *Crustacea* and Spiders, to the beak of Cephalopods, the lower jaw of Vertebrates, &c.

MANTLE. The external integument of most of the Mollusca, which is largely developed, and forms a cloak in which the viscera are protected. Technically called the "pallium."

MANUS (Lat. the hand). The hand of the higher Vertebrates.

MARSIPOBRANCHII (Gr. *marsipos*, a pouch ; *bragchia*, gill). The order of Fishes comprising the Hag-fishes and Lampreys, with pouch-like gills.

MARSUPIALIA (Lat. *marsupium*, a pouch). An order of Mammals in which the females mostly have an abdominal pouch in which the young are carried.

MASTICATORY (Lat. *mastico*, I chew). Applied to parts adapted for chewing.

MAXILLÆ (Lat. jaws). The inferior pair or pairs of jaws in the *Arthropoda* (Insects, Crustacea, &c.) The upper jaw-bones of Vertebrates.

MAXILLIPEDES (Lat. *maxillæ*, jaws ; *pes*, the foot). The limbs in *Crustacea* and *Myriapoda* which are converted into masticatory organs, and are commonly called "foot-jaws."

MEDULLA (Lat. marrow). Applied to the marrow of bones ; or to the spinal cord, with or without the adjective "*spinalis*."

MEDUSÆ. An order of *Hydrozoa*, commonly known as Jelly-fishes (*Discophora*, or *Acalephæ*), so called because of the resemblance of their tentacles to the snaky hair of the Medusa. Many *Medusæ* are now known to be merely the gonophores of *Hydrozoa*.

MEROSTOMATA (Gr. *mēron*, thigh ; *stoma*, mouth). An order of *Crustacea* in which the appendages which are placed round the mouth, and which officiate as jaws, have their free extremities developed into walking or prehensile organs.

MESENTERIES (Gr. *mesos*, intermediate ; *enteron*, intestine). In a restricted sense, the vertical plates which divide the somatic cavity of a Sea-anemone (*Actinia*) into chambers.

MESOPODIUM (Gr. *mesos*, middle; *pous*, foot). The middle portion of the "foot" of Molluscs.

MESOSTERNUM (Gr. *mesos*, intermediate; *sternon*, the breast-bone). The middle portion of the sternum, intervening between the attachment of the second pair of ribs and the xiphoid cartilage (*xiphisternum*).

MESOTHORAX (Gr. *mesos*; and *thorax*, the chest). The middle ring of the thorax in Insects.

MESOZOIC (Gr. *mesos*; and *zoe*, life). The Secondary period in Geology.

METACARPUS (Gr. *meta*, after; *karpos*, the wrist). The bones which form the "root of the hand," and intervene between the wrist and the fingers.

METAMORPHOSIS (Gr. *meta*, implying change; *morphe*, shape). The changes of form which certain animals undergo in passing from their younger to their fully-grown condition.

METAPODIUM (Gr. *meta*, after; *pous*, the foot). The posterior lobe of the foot in *Mollusca*; often called the "operculigerous lobe," because it develops the operculum when this structure is present.

METASTOMA (Gr. *meta*, after; *stoma*, mouth). The plate which closes the mouth posteriorly in the *Crustacea*.

METATARSUS (Gr. *meta*, after; *tarsos*, the instep). The bones which intervene between the bones of the ankle (*tarsus*) and the digits in the hind-foot of the higher Vertebrates.

METATHORAX (Gr. *meta*, after; *thorax*, the chest). The posterior ring of the thorax in Insects.

MIMETIC (Gr. *mimetikos*, imitative). Applied to organs or animals which resemble each other in external appearance, but not in essential structure.

MOLARS (Lat. *mola*, a mill). The "grinders" in man, or the teeth in diphyodont Mammals which are not preceded by milk-teeth.

MOLLUSCA (Lat. *mollis*, soft). The sub-kingdom which includes the Shell-fish proper, the *Polyzoa*, the *Tunicata*, and the Lamp-shells; so called from the generally soft nature of their bodies.

MOLLUSCOIDA (*Mollusca*; Gr. *eidos*, form). The lower division of the *Mollusca*, comprising the *Polyzoa*, *Tunicata*, and *Brachiopoda*.

MONODELPHIA (Gr. *monos*, single; *delphus*, womb). The division of *Mammalia* in which the uterus is single.

MONOMYARY (Gr. *monos*, single; *muon*, muscle). Applied to those bivalves (*Lamellibranchiata*) in which the shell is closed by a single adductor muscle.

MONOPHYODONT (Gr. *monos*; *phuo*, I generate; *odous*, tooth). Applied to those Mammals in which only a single set of teeth is ever developed.

MONOTHALAMOUS (Gr. *monos*; and *thalamos*, chamber). Possessing only a single chamber. Applied to the shells of *Foraminifera* and *Mollusca*.

MONOTREMATA (Gr. *monos*; *trema*, aperture). The order of Mammals comprising the Duck-mole and *Echidna*, in which the intestinal canal opens into a "cloaca" common to the ducts of the urinary and generative organs.

MULTILOCULAR (Lat. *multus*, many; *loculus*, a little purse). Divided into many chambers.

MULTIVALVE. Applied to shells which are composed of many pieces.

MULTUNGULA (Lat. *multus*, many; *ungula*, hoof). The division of Perissodactyle Ungulates, in which each foot has more than a single hoof.

MYRIAPODA or MYRIOPODA (Gr. *murios*, ten thousand; *podes*, feet). A class of *Arthropoda* comprising the Centipedes and their allies, characterised by their numerous feet.

NACREOUS (Fr. *nacre*, mother-of-pearl, originally Oriental.) Pearly; of the texture of mother-of-pearl.

NATATORES (Lat. *nare*, to swim). The order of the Swimming Birds.

NATATORY (Lat. *nare*, to swim). Formed for swimming.

NAUTILOID. Resembling the shell of the *Nautilus* in shape.

NERVURES (Lat. *nervus*, a sinew). The ribs which support the membranous wings of insects.

NEURAL (Gr. *neuron*, a nerve). Connected with the nervous system.

NEURAPOPHYSIS (Gr. *neuron*, a nerve; *apophusis*, a projecting part). The

"spinous process" of a vertebra, or the process formed at the point of junction of the neural arches.

NEUROPTERA (Gr. *neuron;* and *pteron*, a wing). An order of Insects characterised by four membranous wings with numerous reticulated nervures (*e. g.*, Dragon-flies).

NOCTURNAL (Lat. *nox*, night). Applied to animals which are active by night.

NORMAL (Lat. *norma*, a rule). Conforming to the ordinary standard.

NOTOBRANCHIATA (Gr. *notos*, the back; and *bragchia*, gill). Carrying the gills upon the back; applied to a division of the *Annelida.*

NOTOCHORD (Gr. *notos*, back; *chorde*, string). A cellular rod which is developed in the embryo of Vertebrates immediately beneath the spinal cord, and which is usually replaced in the adult by the vertebral column. Often it is spoken of as the "chorda dorsalis."

NUDIBRANCHIATA (Lat. *nudus*, naked; and Gr. *bragchia*, gill). An order of the *Gasteropoda* in which the gills are naked.

NUMMULITES (Lat. *nummus*, a coin). A large coin-shaped Foraminifer of the Eocene period.

OCCIPITAL. Connected with the *occiput*, or the back part of the head.

OCEANIC. Applied to animals which inhabit the open ocean (= pelagic).

OCELLI (Lat. diminutive of *oculus*, eye). The simple eyes of many Echinoderms, Spiders, Crustaceans, Molluscs, &c.

OCTOPODA (Gr. *octo*, eight; *pous*, foot). The tribe of Cuttle-fishes with eight arms attached to the head.

ODONTOCETI (Gr. *odous*, tooth; *ketos*, whale). The "toothed" Whales, in contradistinction to the "whalebone" Whales.

ODONTOID (Gr. *odous; eidos*, form). The "odontoid process" is the centrum or body of the first cervical vertebra (*atlas*). It is detached from the atlas, and is usually anchylosed with the second cervical vertebra (*axis*), and it forms the pivot upon which the head rotates.

ODONTOPHORE (Gr. *odous*, tooth; *phero*, I carry). The so-called "tongue," or masticatory apparatus of *Gasteropoda, Pteropoda*, and *Cephalopoda.*

ŒSOPHAGUS. The gullet or tube leading from the mouth to the stomach.

OLIGOCHÆTA (Gr. *oligos*, few; *chaite*, hair). An order of *Annelida*, comprising the Earth-worms, in which there are few bristles.

OMNIVOROUS (Lat. *omnia*, everything; *voro*, I devour). Feeding indiscriminately upon all sorts of food.

OPERCULATA (Lat. *operculum*, a lid). A division of pulmonate *Gasteropoda*, in which the shell is closed by an operculum.

OPERCULUM. A horny or shelly plate developed in certain *Mollusca* upon the hinder part of the foot, and serving to close the aperture of the shell when the animal is retracted within it; also the lid of the shell of a *Balanus* or Acorn-shell; also the chain of flat bones which cover the gills in many fishes.

OPHIDIA (Gr. *ophis*, a serpent). The order of Reptiles comprising the Snakes.

OPHIDOBATRACHIA (Gr. *ophis; batrachos*, a frog). Sometimes applied to the order of Snake-like Amphibians comprising the *Cæciliæ.*

OPHIOMORPHA (Gr. *ophis; morphe*, shape). The order of *Amphibia* comprising the *Cæciliæ.*

OPHIUROIDEA (Gr. *ophis*, snake; *oura*, tail; *eidos*, form). An order of *Echinodermata*, comprising the Brittle-stars and Sand-stars.

OPISTHOBRANCHIATA (Gr. *opisthen*, behind; *bragchia*, gill). A division of *Gasteropoda* in which the gills are placed on the posterior part of the body.

OPISTHOCŒLOUS (Gr. *opisthen*, behind; *koilos*, hollow). Applied to vertebræ, the bodies of which are hollow or concave behind.

ORAL (Lat. *os*, mouth). Connected with the mouth.

ORNITHODELPHIA (Gr. *ornis*, a bird; *delphus*, womb). The primary division of Mammals comprising the *Monotremata.*

ORNITHOSCELIDA (Gr. *ornis*, bird; *skelos*, leg). Applied by Huxley to the Deinosaurian Reptiles, together with the genus *Compsognathus*, on account of the bird-like character of their hind-limbs.

ORTHOCERATIDÆ (Gr. *orthos*, straight; *keras*, horn). A family of the *Nautilidæ*, in which the shell is straight, or nearly so.

ORTHOPTERA (Gr. *orthos*, straight; *pteron*, wing). An order of Insects.

OSSICULA (Lat. diminutive of *os*, bone). Literally small bones. Often used to designate any hard structures of small size, such as the calcareous plates in the integument of the Star-fishes.

OSTRACODA (Gr. *ostrakon*, a shell). An order of small Crustaceans which are enclosed in bivalve shells.

OTOLITHS (Gr. *ous*, ear; and *lithos*, stone). The calcareous bodies connected with the sense of hearing, even in its most rudimentary form.

OVARIAN VESICLES or CAPSULES. The generative buds of the *Sertularida*.

PACHYDERMATA (Gr. *pachus*, thick; *derma*, skin). An old Mammalian order constituted by Cuvier for the reception of the Rhinoceros, Hippopotamus, Elephant, &c.

PALÆONTOLOGY (Gr. *palaios*, ancient; and *logos*, discourse). The science of fossil remains or of extinct organised beings.

PALÆOTHERIDÆ (Gr. *palaios*, ancient; *ther*, beast). A group of Tertiary Ungulates.

PALÆOZOIC (Gr. *palaios*, ancient; and *zoe*, life). Applied to the oldest of the great geological epochs.

PALLIOBRANCHIATA (Lat. *pallium*; and Gr. *bragchia*, gill). An old name for the *Brachiopoda*, founded upon the belief that the system of tubes in the mantle constituted the gills.

PALLIUM (Lat. *pallium*, a cloak). The mantle of the *Mollusca*. *Pallial*: relating to the mantle. *Pallial line* or *impression*: the line left in the dead shell by the muscular margin of the mantle. *Pallial shell*; a shell which is secreted by, or contained within, the mantle, such as the "bone" of the Cuttle-fishes.

PALPI (Lat. *palpo*, I touch). Processes supposed to be organs of touch, developed from certain of the oral appendages in Insects, Spiders, and Crustacea, and from the sides of the mouth in the Acephalous Molluscs.

PAPILLA (Lat. for nipple). A minute soft prominence.

PARAPODIA (Gr. *para*, beside; *podes*, feet). The unarticulated lateral locomotive processes or "foot-tubercles" of many of the *Annelida*.

PARIETAL (Lat. *paries*, a wall). Connected with the walls of a cavity or of the body.

PATAGIUM (Lat. the border of a dress). Applied to the expansion of the integument by which Bats, Flying Squirrels, and other animals support themselves in the air.

PATELLA. The knee-cap or knee-pan. A sesamoid bone developed in the tendon of insertion of the great extensor muscles of the thigh.

PECTINATE (Lat. *pecten*, a comb). Comb-like; applied to the gills of certain *Gasteropods*, hence called *Pectinibranchiata*.

PECTORAL (Lat. *pectus*, chest). Connected with, or placed upon, the chest.

PEDAL (Lat. *pes*, the foot). Connected with the foot of *Mollusca*.

PEDICELLARIÆ (Lat. *pedicellus*, a louse). Certain singular appendages found in many *Echinoderms*, attached to the surface of the body, and resembling a little beak or forceps supported on a stalk.

PEDICLE (Lat. dim. of *pes*, the foot). A little stem.

PEDIPALPI (Lat. *pes*, foot; and *palpo*, I feel). An order of *Arachnida* comprising the Scorpions, &c.

PEDUNCLE (Lat. *pedunculus*, a stem or stalk). In a restricted sense applied to the muscular process by which certain *Brachiopods* are attached, and to the stem which bears the body (capitulum) in Barnacles.

PEDUNCULATE. Possessing a peduncle.

PELAGIC (Gr. *pelagos*, sea). Inhabiting the open ocean.

PELVIS (Lat. for basin). Applied, from analogy, to the basal portion of the cup (*calyx*) of *Crinoids*. The bony arch with which the hind-limbs are connected in Vertebrates.

PERENNIBRANCHIATA (Lat. *perennis*, perpetual; Gr. *bragchia*, gill). Applied to

those *Amphibia* in which the gills are permanently retained throughout life.

PERGAMENTACEOUS (Lat. *pergamena*, parchment). Of the texture of parchment.

PERIOSTRACUM (Gr. *peri*, around; and *ostrakon*, shell). The layer of epidermis which covers the shell in most of the *Mollusca*.

PERISOME (Gr. *peri*; and *soma*, body). The coriaceous or calcareous integument of the *Echinodermata*.

PERISSODACTYLA (Gr. *perissos*, uneven; *daktulos*, finger). Applied to those Hoofed Quadrupeds (*Ungulata*) in which the feet have an uneven number of toes.

PETALOID. Shaped like the petal of a flower.

PHALANGES (Gr. *phalanx*, a row). The small bones composing the digits of the higher *Vertebrata*. Normally each digit has three phalanges.

PHANEROGAMS (Gr. *phaneros*, visible; *gamos*, marriage). Plants which have the organs of reproduction conspicuous, and which bear true flowers.

PHARYNGOBRANCHII (Gr. *pharugx*, pharynx; *bragchia*, gill). The order of Fishes comprising only the Lancelet.

PHARYNX. The dilated commencement of the gullet.

PHRAGMACONE (Gr. *phragma*, a partition; and *konos*, a cone). The chambered portion of the internal shell of a *Belemnite*.

PHYLACTOLÆMATA (Gr. *phulasso*, I guard; and *laimos*, throat). The division of *Polyzoa* in which the mouth is provided with the arched valvular process known as the "epistome."

PHYLLOPODA (Gr. *phullon*, leaf; and *pous*, foot). An order of *Crustacea*.

PHYSOPHORIDÆ (Gr. *phusa*, air-bladder; and *phero*, I carry). An order of Oceanic *Hydrozoa*.

PHYTOID (Gr. *phuton*, a plant; and *eidos*, form). Plant-like.

PHYTOPHAGOUS (Gr. *phuton*, a plant; and *phago*, I eat). Plant-eating, or herbivorous.

PINNATE (Lat. *pinna*, a feather). Feather-shaped; or possessing lateral processes.

PINNIGRADA (Lat. *pinna*, a feather; *gradior*, I walk). The group of *Carnivora*, comprising the Seals and Walruses, adapted for an aquatic life. Often called *Pinnipedia*.

PINNULÆ (Lat. dim. of *pinna*). The lateral processes of the arms of *Crinoids*.

PISCES (Lat. *piscis*, a fish). The class of Vertebrates comprising the Fishes.

PLACENTA (Lat. a cake). The "after-birth," or the organ by which a vascular connection is established in the higher *Mammalia* between the mother and the fœtus.

PLACENTAL. Possessing a placenta; or connected with the placenta.

PLACOID (Gr. *plax*, a plate; *eidos*, form). Applied to the irregular bony plates, grains, or spines which are found in the skin of various fishes (*Elasmobranchii*).

PLAGIOSTOMI (Gr. *plagios*, transverse; *stoma*, mouth). The Sharks and Rays, in which the mouth is transverse, and is placed on the under surface of the head.

PLANTIGRADE (Lat. *planta*, the sole of the foot; *gradior*, I walk). Applying the sole of the foot to the ground in walking.

PLASTRON. The lower or ventral portion of the bony case of the Chelonians.

PLATYRHINA (Gr. *platus*, broad; *rhines*, nostrils). A group of the *Quadrumana*.

PLEURODONT (Gr. *pleuron*, rib, side; *odous*, tooth). Having the teeth anchylosed with the inner side of the jaws.

PLEURON (Gr. *pleuron*, a rib). The lateral extensions of the shell of *Crustacea*.

PNEUMATIC (Gr. *pneuma*, air). Filled with air.

PODOPHTHALMATA (Gr. *pous*, foot; and *ophthalmos*, eye). The division of Crustacea in which the eyes are borne at the end of long footstalks.

POLLEX (Lat. the thumb). The innermost of the five normal digits of the anterior limb of the higher Vertebrates. In man, the thumb.

POLYCYSTINA (Gr. *polus*, many; and *kustis*, a cyst). An order of *Protozoa*, with foraminated siliceous shells.

POLYPARY. The hard chitinous covering secreted by many of the *Hydrozoa*.

POLYPE (Gr. *polus*, many; *pous*, foot). Restricted to the single individual of a simple *Actinozoön*, such as a Sea-anemone, or to the separate zoöids of a compound *Actinozoön*. Often applied indiscriminately to any of the *Cœlenterata*, or even to the *Polyzoa*.

POLYPIDE. The separate zoöid of a *Polyzoön*.

POLYPIDOM. The dermal system of a colony of a *Hydrozoön*, or *Polyzoön*.

POLYPITE. The separate zoöid of a *Hydrozoön*.

POLYTHALAMOUS (Gr. *polus*; and *thalamos*, chamber). Having many chambers; applied to the shells of *Foraminifera* and *Cephalopoda*.

POLYZOA (Gr. *polus*; and *zoön*, animal). A division of the *Molluscoida* comprising compound animals such as the Sea-mat—sometimes called *Bryozoa*.

POLYZOARIUM. The dermal system of the colony of a *Polyzoön* (= Polypidom).

PORCELLANOUS. Of the texture of porcelain.

PORIFERA (Lat. *porus*, a pore; and *fero*, I carry). Sometimes used to designate the *Foraminifera*, or the *Sponges*.

POST-ANAL. Situated behind the anus.

POST-ŒSOPHAGEAL. Situated behind the gullet.

POST-ORAL. Situated behind the mouth.

PRÆMAXILLÆ—*see* Intermaxillæ.

PRÆMOLARS (Lat. *præ*, before; *molares*, the grinders). The molar teeth of Mammals which succeed the molars of the milk-set of teeth. In man, the bicuspid teeth.

PRÆ-ŒSOPHAGEAL. Situated in front of the gullet.

PRÆ-STERNUM. The anterior portion of the breast-bone, corresponding with the *manubrium sterni* of human anatomy, and extending as far as the point of articulation of the second rib.

PROBOSCIDEA (Lat. *proboscis*, the snout). The order of Mammals comprising the Elephants.

PROCŒLOUS (Gr. *pro*, before; *koilos*, hollow). Applied to vertebræ, the bodies of which are hollow or concave in front.

PROPODIUM (Gr. *pro*, before; *pous*, foot). The anterior part of the foot in Molluscs.

PROSOBRANCHIATA (Gr. *proson*, in advance of; *bragchia*, a gill). A division of Gasteropodous Molluscs in which the gills are situated in advance of the heart.

PROSOMA (Gr. *pro*, before; *soma*, body). The anterior part of the body.

PROTHORAX (Gr. *pro*; and *thorax*, chest). The anterior ring of the thorax of insects.

PROTOPHYTA (Gr. *protos*; and *phuton*, plant). The lowest division of plants.

PROTOPLASM (Gr. *protos*; and *plasso*, I mould). The elementary basis of organised tissues. Sometimes used synonymously for the "sarcode" of the *Protozoa*.

PROTOPODITE (Gr. *protos*, first; and *pous*, foot). The basal segment of the typical limb of a *Crustacean*.

PROTOZOA (Gr. *protos*; and *zoön*, animal). The lowest division of the animal kingdom.

PROXIMAL (Lat. *proximus*, next). The slowly-growing, comparatively-fixed extremity of a limb or of an organism.

PSEUDOPODIA (Gr. *pseudos*, falsity; and *pous*, foot). The extensions of the body-substance which are put forth by the *Rhizopoda* at will, and which serve for locomotion and prehension.

PTEROPODA (Gr. *pteron*, wing; and *pous*, foot). A class of the *Mollusca* which swim by means of fins attached near the head.

PTEROSAURIA (Gr. *pteron*, wing; *saura*, lizard). An extinct order of Reptiles.

PUBIS (Lat. *pubes*, hair). The share-bone; one of the bones which enter into the composition of the pelvic arch of Vertebrates.

PULMOGASTEROPODA (= Pulmonifera).

PULMONARIA. A division of *Arachnida* which breathe by means of pulmonary sacs.

PULMONIFERA (Lat. *pulmo*, a lung; and *fero*, I carry). The division of *Mollusca* which breathe by means of a pulmonary chamber.

PULMONATE. Possessing lungs.
PYRIFORM (Lat. *pyrus*, a pear; and *forma*, form). Pear-shaped.

QUADRUMANA (Lat. *quatuor*, four; *manus*, hand). The order of Mammals comprising the Apes, Monkeys, Baboons, Lemurs, &c.

RADIATA (Lat. *radius*, a ray). Formerly applied to a large number of animals which are now placed in separate sub-kingdoms (*e.g.*, the *Cœlenterata*, the *Echinodermata*, the *Infusoria*, &c.)
RADIOLARIA (Lat. *radius*, a ray). A division of *Protozoa*.
RADIUS (Lat. a spoke or ray). The innermost of the two bones of the fore-arm of the higher Vertebrates. It carries the thumb, when present, and corresponds with the tibia of the hind-limb.
RAMUS (Lat. a branch). Applied to each half or branch of the lower jaw, or mandible, of Vertebrates.
RAPTORES (Lat. *rapto*, I plunder). The order of the Birds of Prey.
RASORES (Lat. *rado*, I scratch). The order of the Scratching Birds (Fowls, Pigeons, &c.)
RATITÆ (Lat. *rates*, a raft). Applied by Huxley to the Cursorial Birds, which do not fly, and have therefore a raft-like sternum without any median keel.
RECTUM (Lat. *rectus*, straight). The terminal portion of the intestinal canal, opening at the surface of the body at the anus.
REPTILIA (Lat. *repto*, I crawl). The class of the *Vertebrata* comprising the Tortoises, Snakes, Lizards, Crocodiles, &c.
REVERSED. Applied to spiral univalves, in which the direction of the spiral is the reverse of the normal—*i.e.*, *sinistral*.
RHIZOPHAGA (Gr. *rhiza*, root; *phago*, I eat). A group of the Marsupials.
RHIZOPODA (Gr. *rhiza*, a root; and *pous*, foot). The division of *Protozoa* comprising all those which are capable of emitting pseudopodia.
RHYNCHOLITES (Gr. *rhunchos*, beak; and *lithos*, stone). Beak-shaped fossils consisting of the mandibles of *Cephalopoda*.
RODENTIA (Lat. *rodo*, I gnaw). An order of the Mammals; often called *Glires* (Lat. *glis*, a dormouse).
RUGOSA (Lat. *rugosus*, wrinkled). An order of Corals.
RUMINANTIA (Lat. *ruminor*, I chew the cud). The group of Hoofed Quadrupeds (*Ungulata*) which "ruminate" or chew the cud.

SACRUM. The vertebræ (usually anchylosed) which unite with the haunch-bones (*ilia*) to form the pelvis.
SAND-CANAL (= STONE-CANAL). The tube by which water is conveyed from the exterior to the ambulacral system of the *Echinodermata*.
SARCODE (Gr. *sarx*, flesh; *eidos*, form). The jelly-like substance of which the bodies of the *Protozoa* are composed. It is an albuminous body containing oil-granules, and is sometimes called "animal protoplasm."
SARCOIDS (Gr. *sarx*; and *eidos*, form). The separate amœbiform particles which in the aggregate make up the "flesh" of a Sponge.
SAURIA (Gr. *saura*, a lizard). Any lizard-like Reptile is often spoken of as a "Saurian;" but the term is sometimes restricted to the Crocodiles alone, or to the Crocodiles and Lacertilians.
SAUROBATRACHIA (Gr. *saura*; *batrachos*, frog). Sometimes applied to the order of the tailed Amphibians (*Urodela*).
SAUROPSIDA (Gr. *saura*; and *opsis*, appearance). The name given by Huxley to the two classes of the Birds and Reptiles collectively.
SAUROPTERYGIA (Gr. *saura*; *pterux*, wing). An extinct order of Reptiles, called by Huxley *Plesiosauria*, from the typical genus *Plesiosaurus*.
SAURURÆ (Gr. *saura*; *oura*, tail). The extinct order of Birds comprising only the *Archæopteryx*.
SCANSORES (Lat. *scando*, I climb). The order of the Climbing Birds (Parrots, Woodpeckers, &c.)
SCAPULA (Lat. for shoulder-blade). The shoulder-blade of the pectoral arch

of Vertebrates; in a restricted sense, the row of plates in the cup of *Crinoids*, which give origin to the arms, and are usually called the "axillary radials."

SCLERENCHYMA (Gr. *skleros*, hard; and *enchuma*, tissue). The calcareous tissue of which a coral is composed.

SCLEROBASIC (Gr. *skleros*, hard; *basis*, pedestal). The coral which is produced by the outer surface of the integument in certain *Actinozoa* (*e.g.*, Red Coral), and forms a solid axis which is invested by the soft parts of the animal. It is called "foot-secretion" by Mr Dana.

SCLERODERMIC (Gr. *skleros*; and *derma*, skin). Applied to the corallum which is deposited within the tissues of certain *Actinozoa*, and is called "tissue-secretion" by Mr Dana.

SCLEROTIC (Gr. *skleros*, hard). The outer dense fibrous coat of the eye.

SCOLECIDA (Gr. *skolēx*, worm). A division of the *Annuloida*.

SCUTA (Lat. *scutum*, a shield). Applied to any shield-like plates; especially to those which are developed in the integument of many Reptiles.

SELACHIA or SELACHII (Gr. *selachos*, a cartilaginous fish, probably a shark). The sub-order of *Elasmobranchii* comprising the Sharks and Dog-fishes.

SEPIOSTAIRE. The internal shell of the Sepia, commonly known as the "cuttle-bone."

SEPTA. Partitions.

SERPENTIFORM. Resembling a serpent in shape.

SERTULARIDA (Lat. *sertum*, a wreath). An order of *Hydrozoa*.

SESSILE (Lat. *sedo*, I sit). Not supported upon a stalk or peduncle; attached by a base.

SETÆ (Lat. bristles). Bristles or long stiff hairs.

SETIFEROUS. Supporting bristles.

SETIGEROUS (=Setiferous).

SETOSE. Bristly.

SIGILLARIOIDS (Lat. *sigilla*, little images). A group of extinct plants of which *Sigillaria* is the type, so called from the seal-like markings on the bark.

SILICEOUS (Lat. *silex*, flint). Composed of flint.

SINISTRAL (Lat. *sinistra*, the left hand). Left-handed; applied to the direction of the spiral in certain shells, which are said to be "reversed."

SIPHON (Gr. *siphon*, a tube). Applied to the respiratory tubes in the *Mollusca*; also to other tubes of different functions.

SIPHONOPHORA (Gr. *siphon*; and *phero*, I carry). A division of the *Hydrozoa* comprising the Oceanic forms (*Calycophoridæ* and *Physophoridæ*).

SIPHONOSTOMATA (Gr. *siphon*; and *stoma*, mouth). The division of *Gasteropodous Molluscs*, in which the aperture of the shell is not "entire," but possesses a notch or tube for the emission of the respiratory siphon.

SIPHUNCLE (Lat. *siphunculus*, a little tube). The tube which connects together the various chambers of the shell of certain *Cephalopoda* (*e.g.*, the Pearly Nautilus).

SIPUNCULOIDEA (Lat. *siphunculus*, a little siphon). A class of *Anarthropoda* (*Annulosa*).

SIRENIA (Gr. *seiren*, a mermaid). The order of *Mammalia* comprising the Dugongs and Manatees.

SOLIDUNGULA (Lat. *solidus*, solid; *ungula*, a hoof). The group of Hoofed Quadrupeds comprising the Horse, Ass, and Zebra, in which each foot has only a single solid hoof. Often called *Solipedia*.

SOMATIC (Gr. *soma*, body). Connected with the body.

SOMITE (Gr. *soma*). A single segment in the body of an Articulate animal.

SPERMATOZOA (Gr. *sperma*, seed; and *zoon*, animal). The microscopic filaments which form the essential generative element of the male.

SPICULA (Lat. *spiculum*, a point). Pointed needle-shaped bodies.

SPIRACLES (Lat. *spiro*, I breathe). The breathing-pores, or apertures of the breathing-tubes (tracheæ) of Insects. Also the single nostril of the Hagfishes, the "blow-hole" of Cetaceans, &c.

SPLANCHNOSKELETON (Gr. *splagchna*, viscera; *skeletos*, dry). The hard structures occasionally developed in connection with the internal organs or viscera.

SPONGE-PARTICLES—*see* Sarcoids.

SPONGIDA (Gr. *spoggos*, a sponge). The division of *Protozoa* commonly known as sponges.

SQUAMATA (Lat. *squama*, a scale). The division of Reptiles comprising the *Ophidia* and *Lacertilia*, in which the integument develops horny scales, but there are no dermal ossifications.

STELLERIDA (Lat. *stella*, star). Sometimes employed to designate the order of the Star-fishes.

STELLIFORM. Star-shaped.

STERNUM (Gr. *sternon*). The breast-bone.

STOLON (Gr. *stolos*, a sending forth). Offshoots. The connecting processes of sarcode, in *Foraminifera;* the connecting tube in the social *Ascidians;* the processes sent out by the cœnosarc of certain *Actinozoa.*

STOMAPODA (Gr. *stoma*, mouth; *pous*, foot). An order of *Crustacea.*

STOMATODE (Gr. *stoma*). Possessing a mouth. The *Infusoria* are thus often called the Stomatode *Protozoa.*

STREPSIPTERA (Gr. *strepho*, I twist; and *pteron*, wing). An order of Insects in which the anterior wings are represented by twisted rudiments.

STREPSIRHINA (Gr. *strepho*, I twist; *rhines*, nostrils). A group of the Quadrumana, often spoken of as *Prosimiæ.*

STYLIFORM (Lat. *stylus*, a pointed instrument; *forma*, form). Pointed in shape.

SUB-CALCAREOUS. Somewhat calcareous.

SUB-CENTRAL. Nearly central, but not quite.

SUB-PEDUNCULATE. Supported upon a very short stem.

SUB-SESSILE. Nearly sessile, or without a stalk.

SUTURE (Lat. *suo*, I sew). The line of junction of two parts which are immovably connected together. Applied to the line where the whorls of a univalve shell join one another; also to the lines made upon the exterior of the shell of a chambered *Cephalopod* by the margins of the septa.

SWIMMERETS. The limbs of *Crustacea*, which are adapted for swimming.

SYMPHYSIS (Gr. *sumphusis*, a growing together). Union of two bones in which there is no motion or but a very limited amount.

SYNAPTICULÆ (Gr. *sunapto*, I fasten together). Transverse props sometimes found in Corals, extending across the loculi like the bars of a grate.

TABULÆ (Lat. *tabula*, a tablet). Horizontal plates or floors found in some Corals, extending across the cavity of the "theca" from side to side.

TACTILE (Lat. *tango*, I touch). Connected with the sense of touch.

TARSO-METATARSUS. The single bone in the leg of Birds produced by the union and anchylosis of the lower or distal portion of the tarsus with the whole of the metatarsus.

TARSUS (Gr. *tarsos*, the flat of the foot). The small bones which form the ankle (or "instep" of man), and which correspond with the wrist (*carpus*) of the anterior limb.

TECTIBRANCHIATA (Lat. *tectus*, covered; and Gr. *bragchia*, gills). A division of *Opisthobranchiate Gasteropoda* in which the gills are protected by the mantle.

TEGUMENTARY (Lat. *tegumentum*, a covering). Connected with the integument or skin.

TELEOSTEI (Gr. *teleios*, perfect; *osteon*, bone). The order of the "Bony Fishes."

TELSON (Gr. *telson*, a limit). The last joint in the abdomen of *Crustacea;* variously regarded as a segment without appendages, or as an azygous appendage.

TERGUM (Lat. for back). The dorsal arc of the somite of an Arthropod.

TERRICOLA (Lat. *terra*, earth; and *colo*, I inhabit). Employed occasionally to designate the Earth-worms (*Lumbricidæ*).

TEST (Lat. *testa*, shell). The shell of *Mollusca*, which are for this reason sometimes called "*Testacea;*" also, the calcareous case of *Echinoderms;* also, the thick, leathery, outer tunic in the *Tunicata.*

TESTACEOUS. Provided with a shell or hard covering.

TETRABRANCHIATA (Gr. *tetra*, four; *bragchia*, gill). The order of *Cephalopoda* characterised by the possession of four gills.

THALASSICOLLIDA (Gr. *thalassa*, sea; *kolla*, glue). A division of *Protozoa*.

THECA (Gr. *theke*, a sheath). A sheath or receptacle.

THECOSOMATA (Gr. *theke*; and *soma*, body). A division of *Pteropodous Molluscs*, in which the body is protected by an external shell.

THERIOMORPHA (Gr. *ther*, beast; *morphe*, shape). Applied by Owen to the order of the Tail-less Amphibians (*Anoura*).

THORAX (Gr. a breastplate). The chest.

TIBIA (Lat. a flute). The shin-bone, being the innermost of the two bones of the leg, and corresponding with the *radius* in the anterior extremity.

TOTIPALMATÆ (Lat. *totus*, whole; *palma*, the palm of the hand). A group of Wading Birds in which the hallux is united to the other toes by membrane, so that the feet are completely webbed.

TRACHEA (Gr *tracheia*, the rough windpipe). The tube which conveys air to the lungs in the air-breathing Vertebrates.

TRACHEÆ. The breathing-tubes of Insects and other articulate animals.

TRACHEARIA. The division of *Arachnida* which breathe by means of tracheæ.

TRILOBITA (Gr. *treis*, three; *lobos*, a lobe). An extinct order of *Crustaceans*.

TROCHANTER (Gr. *trecho*, I turn). A process of the upper part of the thigh-bone (*femur*) to which are attached the muscles which rotate the limb. There may be two, or even three, trochanters present.

TROCHOID (Gr. *trochos*, a wheel; and *eidos*, form). Conical with a flat base; applied to the shells of *Foraminifera* and *Univalve Molluscs*.

TROPHI (Gr. *trophos*, a nourisher). The parts of the mouth in insects which are concerned in the acquisition and preparation of food. Often called "instrumenta cibaria."

TROPHOSOME (Gr. *trepho*, I nourish; and *soma*, body). Applied collectively to the assemblage of the nutritive zoöids of any *Hydrozoön*.

TRUNCATED (Lat. *trunco*, I shorten). Abruptly cut off; applied to univalve shells, the apex of which breaks off, so that the shell becomes "decollated."

TUBICOLA (Lat. *tuba*, a tube; and *colo*, I inhabit). The order of *Annelida* which construct a tubular case in which they protect themselves.

TUBICOLOUS. Inhabiting a tube.

TUNICATA (Lat. *tunica*, a cloak). A class of *Molluscoida* which are enveloped in a tough leathery case or "test."

TURBINATED (Lat. *turbo*, a top). Top-shaped; conical with a round base.

ULNA (Gr. *olene*, the elbow). The outermost of the two bones of the fore-arm, corresponding with the *fibula* of the hind-limb.

UMBELLATE (Lat. *umbella*, a parasol). Forming an umbel—*i.e.*, a number of nearly equal *radii* all proceeding from one point.

UMBILICUS (Lat. for navel). The aperture seen at the base of the axis of certain univalve shells, which are then said to be "perforated" or "umbilicated."

UMBO (Lat. the boss of a shield). The beak of a bivalve shell.

UMBRELLA. The contractile disc of one of the *Lucernarida*.

UNCINATE (Lat. *uncinus*, a hook). Provided with hooks or bent spines.

UNGUICULATE (Lat. *unguis*, nail). Furnished with claws.

UNGULATA (Lat. *ungula*, hoof). The order of *Mammals* comprising the Hoofed Quadrupeds.

UNGULATE. Furnished with expanded nails constituting hoofs.

UNILOCULAR (Lat. *unus*, one; and *loculus*, a little purse). Possessing a single cavity or chamber. Applied to the shells of *Foraminifera* and *Mollusca*.

UNIVALVE (Lat. *unus*, one; *valvæ*, folding-doors). A shell composed of a single piece or valve.

URODELA (Gr. *oura*, tail; *delos*, visible). The order of the Tailed Amphibians (Newts, &c.)

VARICES (Lat. *varix*, a dilated vein). The ridges or spinose lines which mark the former position of the mouth in certain univalve shells.

VASCULAR (Lat. *vas*, a vessel). Connected with the circulatory system.

VENTRAL (Lat. *venter*, the stomach). Relating to the inferior surface of the body.

VERMES (Lat. *vermis*, a worm). Sometimes employed at the present day in the same, or very nearly the same, sense as *Annuloida*, or as *Annuloida* plus the *Anarthropoda*.

VERMIFORM (Lat. *vermis*, worm; and *forma*, form). Worm-like.

VERTEBRA (Lat. *verto*, I turn). One of the bony segments of the vertebral column or backbone.

VERTEBRATA (Lat. *vertebra*, a bone of the back, from *vertere*, to turn). The division of the Animal Kingdom roughly characterised by the possession of a backbone.

VESICLE (Lat. *vesica*, a bladder). A little sac or cyst.

VIBRACULA (Lat. *vibro*, I shake). Long filamentous appendages found in many *Polyzoa*.

VIPERINA (Lat. *vipera*, a viper). A group of the Snakes.

VIVIPAROUS (Lat. *vivus*, alive; and *pario*, I bring forth). Bringing forth young alive.

WHORL. The spiral turn of a univalve shell.

XIPHISTERNUM (Gr. *xiphos*, sword; *sternon*, breast-bone). The inferior or posterior segment of the sternum, corresponding with the "xiphoid cartilage" of human anatomy.

XIPHOSURA (Gr. *xiphos*, a sword; and *oura*, tail). An order of *Crustacea*, comprising the *Limuli* or King-Crabs, characterised by their long sword-like tails.

ZEUGLODONTIDÆ (Gr. *zeugle*, a yoke; *odous*, a tooth). An extinct family of Cetaceans, in which the molar teeth are two-fanged and look as if composed of two parts united by a neck.

ZOÖID (Gr. *zoön*, animal; and *eidos*, like). The more or less completely independent organisms produced by gemmation or fission, whether these remain attached to one another or are detached and set free.

ZOOPHYTE (Gr. *zoön*, animal; *phuton*, plant). Loosely applied to many plant-like animals, such as Sponges, Corals, Sea-anemones, Sea-mats, &c.

INDEX.

PRINTED BY WILLIAM BLACKWOOD AND SONS, EDINBURGH.

III.

INTRODUCTORY TEXT-BOOK OF ZOOLOGY,

FOR THE USE OF JUNIOR CLASSES.

With 127 Engravings. 3s. 6d.

"Very suitable for junior classes in schools. There is no reason why any one should not become acquainted with the principles of the science, and the facts on which they are based, as set forth in this volume."—*Lancet.*

"This is an excellent little work, the value of which school teachers will not be slow to appreciate. . . . It is written throughout clearly and concisely, and has, moreover, the advantage of being profusely illustrated. . . . We hope, before long, to see it in general use."—*Monthly Medical Journal.*

"The book is well suited to become the text-book for schools, and contains nothing that an ordinary schoolboy of thirteen or fourteen could not understand. We hail such a work as tending to the introduction of Natural History teaching in schools, a subject which has hitherto been neglected, owing greatly to the want of such text-books as the one before us."—*Quarterly Journal of Science.*

"This capital introduction to natural history is illustrated and well got up in every way, a credit alike to author and publisher. We should be glad to see it generally used in schools."—*Medical Press and Circular.*

"Nothing can be better adapted to its object than this cheap and well written introduction."—*London Quarterly Review.*

IV.

ADVANCED TEXT-BOOK OF ZOOLOGY,

FOR THE USE OF SCHOOLS.

Crown 8vo, with numerous Engravings. 6s.

"The author's Text-book, regarded from this point of view, is a decided success; it is just what was wanted. The subject has been treated in a scientific spirit, but at the same time so clearly and well as to be quite within the comprehension of any young student who will bring ordinary attention to his task."—*Lancet.*

"Throughout the work the information is brought up to the most advanced state of our knowledge, and the explanations and descriptions are clear, and, where necessary, illustrated by diagrams and figures."—*Educational Times.*

"This is an excellent treatise for its purpose. Dr Nicholson's style is singularly intelligent; he conveys much information in a small space, and is especially clear in his explanations of the various zoological classes and their characteristics. The introductory chapter is a model of lucid writing on a difficult point, the distinctions between plants and animals. . . . We have only to add that Christian teachers and the adherents of a spiritual philosophy may safely put this book into the hands of their pupils. There is nothing theological in the book, but, on the other hand, there is nothing anti-theological."—*Nonconformist.*

"As a means of imparting an elementary knowledge of zoology, so far as concerns the classification of the various members of the animal kingdom and the description of the most obvious and distinctive characters of the various classes and orders, this book deserves a hearty approval. The descriptions are simple and intelligible; and the work is well illustrated with wood engravings."—*British Medical Journal.*

"We can very cordially recommend the work, and feel sure that an earnest teacher, with the help of a microscope to illustrate the earlier sections of the book, with a few specimens for class-demonstration, and with a full belief in the power of Natural History to interest intelligent observers, cannot fail to awaken mind, and at the same time to train his pupils to habits of correct and profitable observation."—*Quarterly Journal of Science.*

"Dr Alleyne Nicholson has brought out the best Advanced Text-Book of Zoology that has yet appeared. It is of small bulk, well arranged, and illustrated by a considerable number of woodcuts. A careful reader will learn from it more of the principles of scientific classification, and get a better notion of the anatomical and physiological considerations on which it depends, than from any similar work we could name. . . . It would be extremely valuable to have this book read in the upper classes of good schools. Any intelligent teacher could learn from it quite enough to offer necessary explanations; and the way in which Dr Nicholson works up his facts so as to illustrate principles, places his book far in advance of ordinary manuals, and would insure pupils being interested in his teaching."—*The Student.*

V.

EXAMINATIONS IN NATURAL HISTORY;

BEING A PROGRESSIVE SERIES OF QUESTIONS ADAPTED TO THE AUTHOR'S 'INTRODUCTORY AND ADVANCED TEXT-BOOKS,' AND 'THE STUDENT'S MANUAL OF ZOOLOGY.'

1s., Post-free.

The Author's object in compiling this series of questions has been to assist the Teacher whose limited time does not admit of so careful a preparation of his examinations as the subject demands, and, at the same time, to bring within reach of the Student the ready means of testing his own proficiency in the Science.

VI.

INTRODUCTION TO THE STUDY OF BIOLOGY.

Crown 8vo, with numerous Engravings. 5s.

"Nowhere else, we believe, can the student, whether he be the theologian anxious to learn the set of the tide and the direction of the under-current of thought of modern science and philosophy, the man of letters, or the medical student, or, lastly, the practitioner who is not quite ignorant of the elements of comparative anatomy, but is slightly puzzled with such new terms as Homogeny and Homoplasy, Abiogenesis and Bioplasm; nowhere else, we believe, can these meet with such clear definitions, and with such fair expositions of rival theories, as in the pages before us."—*Medical Press.*

"Admirably written and fairly illustrated, and brings within the compass of 160 pages the record of investigations and discoveries scattered over so many volumes. Seldom indeed do we find such subjects treated in a style at once so popular and yet so minutely accurate in scientific detail."—*Scotsman.*

"In all the questions upon which he touches, Dr Nicholson shows himself thoroughly master of his subject; and when he has to deal with disputed points, his moderation and fairness are no less worthy of praise than the clearness and logical force with which he states his own conclusions. The chapters on Abiogenesis and Origin of Species, though necessarily concise, are enough to make us hope that we shall have something more on the same subjects from Dr Nicholson."—*Standard.*

"A work that might well be taken as a text-book for the higher classes in schools."—*Lancet.*